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# *The Journal of*
# THE ROYAL AERONAUTICAL SOCIETY

CONTENTS NOVEMBER 1950

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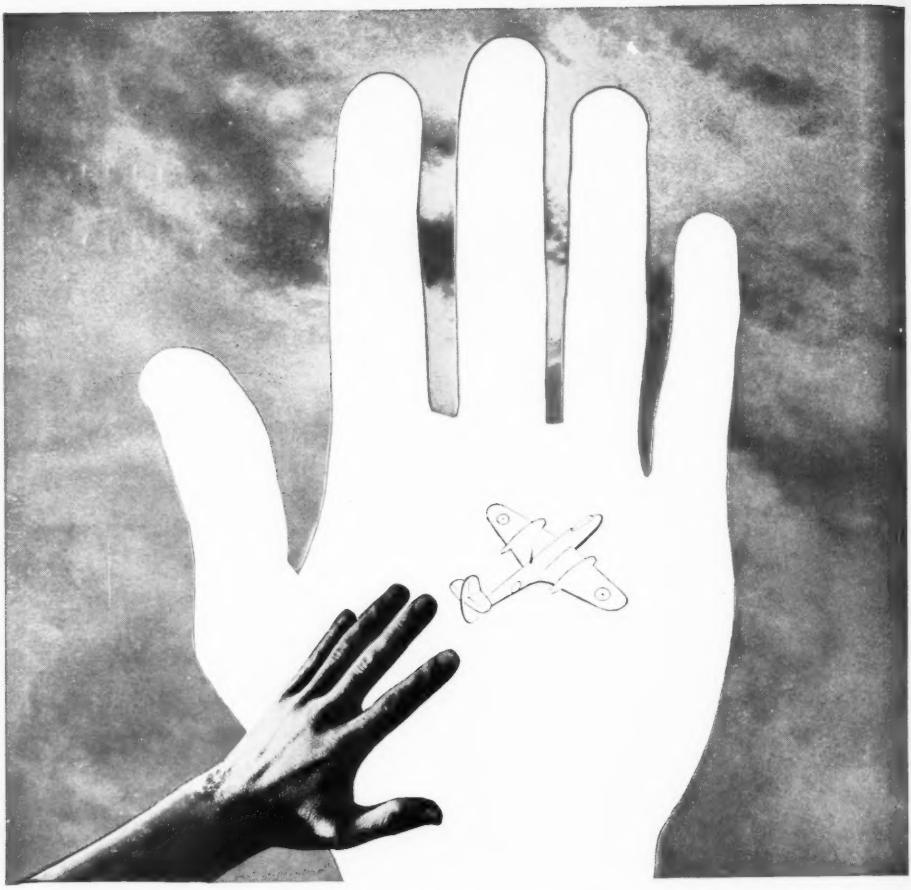
REVIEWS

LONDON
ROYAL AERONAUTICAL SOCIETY, 4 HAMILTON PLACE, W.1



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# GRADUATES' AND STUDENTS' SECTION

*November* 1950

## SOME NOTES ON THE TERMS "$g$" AND "INERTIA"

By M. C. CAMPION, B.Sc.(Eng.), Grad.R.Ae.S.

PART III (*continued*)

(*Parts I and II were published with the August* JOURNAL *and the first sections of Part III were published with the October* JOURNAL)

III—*The loads on an aeroplane, and the resulting inertia factors (continued)*

Paragraphs (*i*) and (*ii*) defined the notation used and paragraph (*iii*) described "flight at one $g$."

(*iv*) The handbooks of strength requirements specify, in the form of a "flight envelope," the maximum value, at any speed, of the normal acceleration for which the structure should be designed. This condition of flight (pure normal acceleration) can best be visualised as one in which the aircraft is flying along a circular path, the acceleration being the centrifugal acceleration required to maintain it on that path.

The specified accelerations, $n_1$, $n_2$, and so on, are absolute values (in "$g$'s") and include the acceleration due to gravity. In other words, steady level flight is represented by $n=1$.

Let the acceleration be $n$ "$g$'s"; if this is purely normal to the flight path, then there will be no pitching moment about the C.G. of the aircraft. The total lift will be balanced by a vertical inertia force of $nW$, and equations (9) and (10) will be replaced by:

$$L_W + L_T = nW \quad . \quad . \quad . \quad (11)$$

$$M_0 + L_W(h-h_0)\bar{c} + M_T - L_T \, . \, l_T = 0 \quad . \quad . \quad . \quad (12)$$

The flight speed and the corresponding value of $n$ are known, hence the loads can be found. The inertia factor for the whole aircraft will be $n$. These cases are known as "flight envelope cases with no pitching acceleration."

(*v*) If, while the aircraft is in this condition, the pilot moves the elevator controls, the tail load will change and the aircraft will pitch. This pitching motion will be assumed to occur before the speed of the aircraft can change.

Because the flight speed does not change, the additional tail load will act at B, the aerodynamic centre of the tailplane. Then for instantaneous equilibrium:

$$L_W + L_T + P = n'W \quad . \quad . \quad . \quad (13)$$

$$M_0 + L_W(h-h_0)\bar{c} + M_T - (P+L_T)l_T = \alpha I_P \quad . \quad . \quad . \quad (14)$$

where $L_W$, $L_T$, $M_0$ and $M_T$ have the same values as in equations (11) and (12). Since the total vertical load has changed, the normal acceleration will no longer be $n$, but will be $n'$, and as the inertia factor is numerically equal to the acceleration in "$g$'s," the new normal factor is

$$n' = (L_W + L_T + P)/W = n + P/W \quad . \quad . \quad . \quad . \quad (15)$$

The angular inertia factor in pitch is given by

$$\alpha = [M_0 + L_W(h-h_0)\bar{c} + M_T - (P+L_T)l_T]/I_P = -Pl_T/I_P \quad . \quad . \quad (16)$$

The resultant normal factor then varies along the length of the aircraft, being increased forward of the C.G. and reduced aft of it, or vice-versa, according to the sense of $\alpha$. It should be noted that both inertia factors act in the opposite direction to the actual accelerations of the aircraft.

The cases described are known as "flight envelope cases with pitching acceleration."

*NOTE:* The assumption made, that the total lift alters when the tail load changes, leads to a change in the normal acceleration. The strength requirements may specify that the acceleration shall be $n$ after the change of tail load, in which case the values of $L_W$, $L_T$ and $M_T$ must be adjusted so that:

$$L'_W + L'_T + P = nW \quad . \quad . \quad . \quad . \quad . \quad (17)$$

(*vi*) Suppose the aircraft to be flying straight and level, at "one $g$," when it suddenly encounters a vertical gust. This causes a change in the angle of incidence, while instantaneously, the flight speed remains the same. The lift on the wing and tailplane will change, and the aircraft will experience a vertical acceleration. Since the flight speed is unchanged, the additional lift forces will act at the aerodynamic centres of the surfaces, and for instantaneous equilibrium,

$$L_W + \Delta L_W + L_T + P = nW \quad . \quad . \quad (18)$$

$$M_0 + (L_W + \Delta L_W)(h - h_0)\bar{c} + M_T - (P + L_T)l_T = \alpha I_P \quad . \quad . \quad (19)$$

where $L_W$, $L_T$, $M_0$ and $M_T$ are the values appropriate to flight at one $g$, and $\Delta L_W$, $P$ are the increments of wing lift and tail load due to the gust. Hence, from equations (9) and (10), the inertia factors are:

$$n = (L_W + \Delta L_W + L_T + P)/W = 1 + (\Delta L_W + P)/W \quad . \quad . \quad (20)$$

$$\alpha = [M_0 + (L_W + \Delta L_W)(h - h_0)\bar{c} + M_T - (P + L_T)l_T]/I_P$$
$$= [\Delta L_W (h - h_0)\bar{c} - Pl_T]/I_P \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

Due to the change of drag caused by the change in incidence, the aircraft will also have an acceleration along the flight path, which is balanced by an equal and opposite inertia force, $dW$, from which the forward or aft inertia factor, $d$, can be deduced.

These conditions are not realised in actual flight, since the aircraft does not suddenly fly completely into a gust. To avoid the tedious calculations involved in estimating the exact effects of a gust, a simplified method is adopted, in which the whole aircraft is imagined to fly into an "equivalent sharp edged gust," whose value is less than that of the true gust. Details of the method will be found in the handbooks of strength requirements referred to in paragraph (*ii*) of this part of the paper (*see* October JOURNAL).

(*vii*) The result of a gust acting along the flight path will be a change in the flight speed. The changes in the lift, drag and pitching moment on the aircraft can be estimated, and the inertia factors found by methods similar to those described above.

(*viii*) In all the cases mentioned, normal accelerations are assumed to be normal to the flight path, since the aerodynamic lift loads are measured in this direction. For stressing purposes, it is often more convenient to determine the accelerations and inertia factors relative to an axis which is fixed in the aircraft. If the angle of incidence of this axis (usually the fuselage datum) to the flight path is known for each stressing case, the resultant components of the normal and fore-and-aft accelerations or inertia factors can be easily found.

It will usually be found that the normal factor is practically the same whichever axis is chosen, since the larger part of it is a function of the cosine of the angle of incidence of the datum, which is usually a small angle. In the low speed cases, where the aircraft is at stalling incidence, the normal factor will be changed by a greater amount.

In either case, the component of the acceleration acting along the datum line may differ greatly from the acceleration along the flight path. The resulting inertia factor will usually be small compared with the normal factor.

(*To be continued*)

THE ROYAL AERONAUTICAL SOCIETY
4 HAMILTON PLACE, PICCADILLY, LONDON, W.1. GROSVENOR 3515-9

# NOTICES NOVEMBER 1950

## CONTENTS OF THE NOVEMBER JOURNAL

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A Comparative Study of the Noise from Turbo-jet and Reciprocating Aircraft Engines in Flight, S. C. Ghose, Ph.D., B.Sc., A.M.I.E.E.

The Anticlastic Curvature of Rectangular Beams and Plates, D. G. Ashwell, M.A.

Reviews.

**The Council are particularly anxious to encourage members of the Society to support their own Journal by contributions to it of articles and papers on any aspect of Aeronautics. For that purpose they have set aside £250 a year in the form of premium awards to the authors (members or non-members) of such papers as some reimbursement for the work which has been done by the author. These premium awards are not fixed but vary from five to twenty guineas normally. It is hoped therefore that those members who have written papers on their special subjects will consider their own Journal in the first place.**

## THE JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY

It is regretted that with the increasing costs of production it has been found necessary to increase the price of the JOURNAL OF THE SOCIETY.

From January 1951 (Volume LV, Number 481) the price will be increased from 7s. 6d. to 10s. 0d. for each number.

**The new rates from January 1951 therefore will be:—**

Single Copies: 10s. 3d. each including postage (home or abroad)

Annual Subscription: £6 3s. 0d. including postage (home or abroad)

## THE AERONAUTICAL QUARTERLY—PART III, VOLUME II

Part III, Volume II of "The Aeronautical Quarterly" will be available towards the end of November from the offices of the Society at 7s. 9d. a copy to members of the Society, post-paid, or 10s. 3d. to non-members, post-paid.

*The Contents of Part III are:—*

| | | |
|---|---|---|
| Beams on Elastic Supports and on Cross-Girders | ... | J. M. Klitchieff |
| The Estimation of Range of Jet-Propelled Aircraft | ... | H. Pearson |
| On Non-Steady Motion of Slender Bodies ... | ... | John W. Miles |

| | |
|---|---|
| The Correction of Wind Tunnel Nozzles for Two-Dimensional Supersonic Flow ... ... ... ... | R. E. Meyer and M. Holt |
| Some Developments of Expansion Methods for Solving the Flutter Equations ... ... ... ... ... | John Williams |

*The Contents of Part II, Volume II, copies of which are still available are*:—

| | |
|---|---|
| Critical Mach Numbers for Swept-Back Wings ... ... | S. Neumark |
| General Performance Reduction Equations for Reciprocating-Engined Aircraft with Constant-Speed Propellers ... | W. J. Annand |
| The Axially-Symmetrical Supersonic Flow Near the Centre of an Expansion ... ... ... ... ... ... | N. H. Johannesen and R. E. Meyer |
| Note on the Dependence of Flap Hinge Moment Derivatives on Hinge Position ... ... ... ... ... ... | W. J. Duncan |
| On the Chordwise Lift Distribution at the Centre of Swept Wings ... ... ... ... ... ... ... | D. Küchemann and J. Weber |
| Amendments to: "A Note on the Bending Moment Induced in the Booms of a Spar at the point of Application of a Concentrated Load" (Volume I Part IV) ... | H. F. Winny |

*The Contents of Part I Volume II, copies of which are still available, are*:—

| | |
|---|---|
| Two-Dimensional Theory of Stiffened Plates ... ... | Chang O'Chou |
| The Whirling of a Spinning Top ... ... ... ... | J. Morris |
| The Possibility of the Determination of Rate of Climb from Acceleration Measurements in Level Flight ... | E. C. Pike |
| A Note on Subsonic Aerofoil Theory ... ... ... | John W. Miles |
| Theory of an Oscillating Supersonic Aerofoil ... ... | Geoffrey L. Sewell |
| The Linearised Theory of Conical Fields in Supersonic Flow, with Applications to Plane Aerofoils ... ... | S. Goldstein and G. N. Ward |

**A few copies of Parts I to IV, Volume I are still available but members are reminded that a strictly limited edition only of "The Aeronautical Quarterly" is printed and numbers cannot be reprinted in any circumstances. An annual subscription therefore is advisable.**

## ANGLO-AMERICAN AERONAUTICAL CONFERENCE—1951

The Third Anglo-American Aeronautical Conference, convened jointly by the Royal Aeronautical Society and the Institute of the Aeronautical Sciences (of America), will be held at Brighton, Sussex, during September 1951.

Previous Conferences have been held in London in 1947 and in New York in 1949.

Further information will be issued as soon as it is available.

## MEMBERS' NEW APPOINTMENTS

J. C. Barrett (*Associate Fellow*)—Assistant Engineer (Engineer III), Ministry of Supply, IA/Rocket Propulsion Dept., R.A.E., Westcott, Bucks.

A. D. Baxter (*Associate Fellow*)—Chair of Aircraft Propulsion, College of Aeronautics.

Hedley S. Crabtree (*Associate Fellow*)—Director, Hedley S. Crabtree & Co. Ltd., Consultant Engineers.

E. Earnshaw (*Associate Fellow*)—Director, Plessey Co. Ltd.

Stanley H. Evans (*Fellow*)—Project Design Office, Short Bros. & Harland Ltd., Belfast.

F. Hearle (*Fellow*)—Chairman, de Havilland Aircraft Company Ltd.

W. S. Hemp, M.A. (*Associate Fellow*)—Chair of Aircraft Structures and Aeroelasticity in the Department of Aircraft Design, College of Aeronautics.

L. J. Lindlam (*Associate Fellow*)—Engineering Tutor at Huddersfield Training College for Technical Teachers.

J. B. B. Owen (*Associate Fellow*)—John William Hughes' Chair of Civil Engineering at University of Liverpool.

W. E. W. Petter (*Fellow*)—Deputy Managing Director, Folland Aircraft Ltd.

J. A. C. Williams (*Associate Fellow*)—Engineering Staff of Guthrie & Co., Singapore.

H. T. Chapman (*Associate Fellow*)—Managing Director, Armstrong Siddeley Motors Ltd.

## COMMITTEE MEETINGS IN OCTOBER

A meeting of the Council was held in the offices of the Society on 26th October 1950. Among the items discussed was the report of the Lectures Committee on the Spring 1951 Lecture programme; the report of the Grading Committee; Liaison with other Bodies; the report of the Education and Examinations Committee dealing with examinations exempting from the Associate Fellowship examination; and a report on the 1950 Garden Party.

During October nine meetings were held by Committees of the Society. Outside bodies engaged in aircraft engineering and research held 19 meetings in the offices of the Society.

## NEWS OF THE BRANCHES AND DIVISIONS

The President of the Society, Major G. P. Bulman, C.B.E., visited the Bristol Branch of the Society on Monday, 23rd October and the Reading Branch on Wednesday, 25th October. He hopes to visit most of the Branches of the Society during his term of office. The Secretary, Captain J. L. Pritchard, C.B.E., visited the Halton Branch of the Society, on 14th October.

Mr. T. T. N. Coleridge, A.F.R.Ae.S., Honorary Secretary of the New Zealand Division, was entertained to lunch in the offices of the Society on the 25th October by the President and others, during which questions affecting the Division and the main Society were discussed.

## THE CIERVA MEMORIAL PRIZE

The closing date for entries for the 1950/51 Cierva Memorial Prize (£25) which is offered annually by the Helicopter Association of Great Britain, is *31st March 1950*. The prize is awarded for the best essay or paper of a technical nature received on any subject directly connected with rotating wing aircraft. Competitors may be of any nationality and should be less than 35 years of age on 31st December 1950. Full particulars of the Competition may be obtained from the Assistant Secretary, The Helicopter Association of Great Britain, Londonderry House, 19 Park Lane, London, W.1.

## LECTURES—AUTUMN 1950

### MAIN LECTURES

*(At 6 p.m. in the Lecture Hall of the Institution of Civil Engineers, Great George Street, London, S.W.1, unless otherwise stated. Tea will be served at 5.30 p.m.)*

**Thursday, 23rd November 1950**—Rockets and Assisted Take-off, A. V. Cleaver, A.R.Ae.S.

**Thursday, 7th December 1950**—A DISCUSSION—The Relative Merits of Centrifugal and Axial Compressors for Aircraft Gas Turbines, H. Pearson, B.A., A.F.R.Ae.S. and Dr. E. S. Moult, B.Sc., F.R.Ae.S., M.I.Mech.E.

**Thursday, 14th December 1950**—Clear Air Turbulence Over Europe, Dr. G. S. Hislop, B.Sc., A.R.T.C., M.I.Mech.E., A.F.R.Ae.S.

### SECTION LECTURES

*(At 7 p.m. in the Library of the Royal Aeronautical Society, 4 Hamilton Place, London, W.1, unless otherwise stated.)*

**Tuesday, 14th November 1950**—Operational Problems of Public Transport Helicopters, R. H. Whitby, B.Sc., A.R.C.S., D.I.C., A.F.R.Ae.S.

**Tuesday, 28th November 1950**—Metal Adhesive Processes, F. H. Parker.

**Tuesday, 5th December 1950**—Aircraft Production, Prof. J. V. Connolly, B.E., F.R.Ae.S.

### GRADUATES' AND STUDENTS' LECTURES

*(At 7.30 p.m. in the Library of the Royal Aeronautical Society, 4 Hamilton Place, W.1, unless otherwise stated. Visitors are welcome to attend.)*

**Thursday, 9th November 1950**—Work in the High-Speed Tunnel, F. G. Irving, B.Eng., Grad.R.Ae.S.

**Thursday, 30th November 1950**—High-Speed Flying, Sqdn. Ldr. J. Derry, D.F.C.

**Tuesday, 12th December 1950**—Film Show, by W. Courtenay, O.B.E., M.M., A.R.Ae.S.

## BRANCH LECTURES AND NOTICES

Notices of Branch Lectures and Meetings for inclusion in the Monthly Notices of the Society must be received by the 20th of the preceding month. The Honorary Secretaries of all Branches are asked to inform the Society of their arrangements for meetings so that a complete list of Branch meetings may be given.

### BIRMINGHAM BRANCH

**Friday, 24th November 1950**—A Review of Aerodynamic Cleanness, Professor E. J. Richards, M.A., B.Sc., F.R.Ae.S.
At Wolverhampton, at 7.30 p.m.

**Friday, 15th December 1950**—Radar and Kindred Pilot Aids.
At the Chamber of Commerce, Birmingham, at 7.30 p.m.

## BRISTOL BRANCH

**Wednesday, 15th November 1950**—Present Trends of Industrial Gas Turbine Development, R. G. Voysey, A.C.G.I., D.I.C., Wh.Sc., A.M.I.Mech.E. (*Joint Meeting with the Institutions of Mechanical and Electrical Engineers to be held at the Royal Fort Physics Laboratory, Bristol, at 7 p.m.*)

**Monday, 27th November 1950**—(Section Lecture)—Landing Gear Design, H. G. Conway, M.A., F.R.Ae.S., A.M.I.Mech.E.

**Monday, 4th December 1950**—Physical Aspects of Compressible Flow and Shock Waves, Joseph Black, M.Sc., A.F.R.Ae.S.

In the Conference Room, Filton House, The Bristol Aeroplane Co. Ltd. at 6 p.m. unless otherwise stated.

## BROUGH BRANCH

**Wednesday, 15th November 1950**—Aircraft in Future Warfare, Air Marshal Sir Robert Saundby, K.B.E., C.B., M.C., D.F.C., A.F.C.

**Wednesday, 6th December 1950**—Members' "Lecturette" Night.
In the Lecture Hall, Electricity Showrooms, Ferensway, Hull, at 7.30 p.m.
Admission is by ticket only.

## COVENTRY BRANCH

**Wednesday, 15th November 1950**—Flutter, H. Templeton, B.Sc., A.F.R.Ae.S.

**Wednesday, 13th December 1950**—Films.
In the Wine Lodge Hotel, The Burges, Coventry, at 7.30 p.m.

## DERBY BRANCH

**Monday, 4th December 1950**—Annual General Meeting followed by an "Aeronautical Quiz."

In the Rolls-Royce Welfare Hall, Nightingale Road, Derby, at 6.15 p.m.

## GLASGOW BRANCH

**Monday, 20th November 1950**—Two Films: Aircraft Review for 1949 and Refinery Processes—Gasoline.

**Friday, 15th December 1950**—Annual General Meeting.
At St. Enoch Hotel, Glasgow, at 7.30 p.m.

## GLOUCESTER AND CHELTENHAM BRANCH

**Wednesday, 22nd November 1950**—Recent Developments in Aircraft Hydraulics, D. P. Amor, B.Sc., A.F.R.Ae.S.

At Wheatstone Hall, City Library, Gloucester, at 7.30 p.m.

**Saturday, 25th November 1950**—*A visit* to the Bristol Aeroplane Co. Ltd.

## HATFIELD BRANCH

**Wednesday, 22nd November 1950**—Aviation Medicine, Dr. K. G. Bergin, A.F.R.Ae.S.

In the Senior Staff Mess, de Havilland Aircraft Co. Ltd., Hatfield, at 6.15 p.m.

LEICESTER BRANCH

**Wednesday, 8th November 1950**—The Aeroplane as a Commercial Product, Captain K. J. G. Bartlett.

**Wednesday, 13th December 1950**—Research in Civil Aviation, N. E. Rowe, C.B.E., B.Sc., F.R.Ae.S.

At the College of Technology, Room 104, at 7.15 p.m.

LUTON BRANCH

**Wednesday, 22nd November 1950**—Discussion Evening. Papers by Branch Members.

**Wednesday, 6th December 1950**—Aircraft Maintenance, B. S. Shenstone, M.A.Sc., F.R.Ae.S., A.F.I.Ae.S.

At the George Hotel, Luton, at 7.30 p.m.

PORTSMOUTH BRANCH—FILM PROGRAMME

**Thursday, 16th November 1950**—Welding Aluminium (Aluminium Development Association).

**Thursday, 30th November 1950**—Petroleum (Shell Petroleum Co.).

**Thursday, 14th December 1950**—Oxy-Acetylene Welding (British Oxygen Co.).

At the Apprentices' School, Airspeed Ltd., The Airport, Portsmouth, at 6 p.m.

READING AND DISTRICT BRANCH

**Thursday, 30th November 1950**—Car Design and Testing for Quantity Production, A. F. Houlberg, A.R.Ae.S.

At the Abbey Gateway Rooms, at 7.30 p.m.

SOUTHAMPTON BRANCH

**Wednesday, 29th November 1950**—The Control of Direct Coupled Gas Turbine Propeller Engines, W. H. Lindsey, M.A., F.R.Ae.S.

In the Physics Lecture Theatre, University College, at 7 p.m.

WEYBRIDGE BRANCH

**Wednesday, 29th November 1950**—A Film Show.

**Wednesday, 13th December 1950**—Designing for High Speed, Professor E. J. Richards, M.A., B.Sc., F.R.Ae.S.

**Friday, 29th December 1950**—Annual Dance.

At Vickers-Armstrongs Ltd., Weybridge, at 6 p.m.

## CHANGES OF ADDRESS

To assist in keeping the records of members correct and up to date the Secretary will be glad if all members will notify him as soon as possible of changes of address.

When notifying changes please give the following particulars:—

Name (in block letters).
Grade of membership.
New address (in block letters).
Old address.

Changes of address must be received *before the 15th of the month* in order to be effective for the Journal for the following month.

## JOURNAL BINDING

The prices of binding of Journals are as follows:—

1949 Volume (including packing and postage), 15s. 6d.

Previous Volumes (including packing and postage), 17s. 0d.

Journals should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the offices of the Society.

Cases only for unbound 1949 Volumes are available, price 6s. 6d. each. Requests for cases, with remittances, should be sent to the Secretary at the offices of the Society.

## LAPEL BADGES

Lapel badges are still available to members at 3s. 6d. each, including postage. These badges are gilt enamel with a screw back and are $\frac{3}{4}$ inch in diameter. Remittances should be sent, with applications, to the Secretary at the offices of the Society.

## ELECTIONS

The following is a list of new members and transfers of membership of the Society:—

*Associate Fellows*

George Robert Allison (from Associate), Nelson William Maclean Beatts, James Francis Berry (from Graduate), Ronald John Brocklehurst (from Graduate), Kevin Edmunds Cheverton (from Graduate), Francis Jeffrey Colville (from Graduate), Leslie Frank Compton, William Fisher, William Anthony Walter Fox, Frederick Hodson, Dennis Albert Logan (from Graduate), Alan Bycroft Lowe (from Graduate), Jag Nath Mathur, Robert Hellyar Perrott (ex-Graduate), John Clifford Pope, Ian Wedderburn Clunie Robertson (from Graduate), Harold Martin Russel, Alec Simon, Sidney John Smith (from Graduate), Kenneth George Standell (from Graduate), Raymond Kenneth Peter Stevens (from Graduate), Charles Leonard Trevithick (from Associate), Edward Elijah Weekley (from Associate), Maurice Oliver Wilmer (from Graduate), Ronald Anderson Wood, Ivor Edward Woodroffe (from Graduate), Peter William Wreford-Bush (from Graduate), Dennis Wright (from Graduate).

*Associates*

William Gordon Bailey, John Robert Batt, Peter Kenneth Brack, Frank Brookesmith, Leonard Ernest Bunnett, William Burley, Reginald Arthur Coates, Sidney Arthur Cooper, Patrick Jerard Crowley, William Thomas Elson, John Foster Ferguson, Richard Albert Fuller, Ronald Basil Griffiths, John Harston, Frederick Maurice McGregor, Nelson William Maskell, Thomas Sivewright Middleton, Bertram Arthur Morris, Peter Hugh Raymond, Robert James Varner Russell, Graham Robertson Stroud, Reginald Vaughan Grant Tunstall, John Ashworth Tupman (from Student), Victor Alfred Vagg, Gerald Edward Wills, Norman David Wolf, John Wood-Collins.

*Graduates*

Clifford John Benjamin (from Student), John Nobel Cochrane, David John Cockrell, Arthur Haydon Craven, Eric Leonard Hassell (from Student), George Hughes, Donald Roy Lewis, Andrew Colin Nicholls, Edward Norman Palmer, John Thomas Pratt, Alan Hugh Stenning (from Student), Robert Keith Turton, John Walker, Arthur Frank Albert Watts (from Student).

*Students*

Richard Durnford, Gerald William East, Jack Womersley Headley, Peter Kennett, Joseph William Herbert Dennis Lovell, Michael Martin Marsh, Zdenek A. Navratil, Harold Alexander Simon, Peter Hubert Swift, John Edward Wingate, Krishna Murthy Narayana Murthy Yellhanka.

*Companion*

Sobhi Ahmed Ali.

## ACKNOWLEDGMENTS

The Council acknowledge with grateful thanks the return of back numbers of the Journal from R. W. Corkling, Esq., *Associate Fellow*; and Alfred Ryan, Esq., *Associate Fellow*.

## ADDITIONS TO THE LIBRARY

The following have been added to the Library (titles of pamphlets are printed in italics and books marked * or ** may not be taken out on loan):—

| | |
|---|---|
| *Aeronautical Research Committee | Technical Report 1939. Two Volumes. H.M.S.O. 1949/50. |
| *Bridgman, L. (Editor) | Jane's All the World's Aircraft. 1950/51. Sampson Low. 1950. |
| *British Standards Institution | Glossary of Aeronautical Terms. B.S.185. Part I. B.S.I. 1950. |
| Church, A. H. | Elementary Mechanical Vibrations. Pitman (N.Y.). 1948. |
| Drake, R. H. | Aircraft Engine Maintenance and Service. Macmillan (N.Y.). 1950. |
| Fair, M. L. and E. W. Williams | Economics of Transportation. Harper & Bros. (N.Y.). 1950. |
| Fairchild Engine & Airplane Corp. | Heat Transfer Lectures. Two Volumes. Nepa Division, Oak Ridge. 1948/49. |
| Freudenthal, A. M. | Inelastic Behaviour of Engineering Materials and Structures. Wiley. 1950. |
| Gailer, J. W. and E. J. Vaughan | Protective Coatings for Metals. Griffin. 1950. |
| Harper, H. | Ace Air Reporter. Scientific Book Club. 1944. |
| Judge, A. W. | Modern Gas Turbines. Second Edition. Chapman & Hall. 1950. |
| Katz, I. | Principles of Aircraft Propulsion Machinery. Pitman (N.Y.). 1950. |
| Latimer-Needham, C. H. | Refuelling in Flight. Pitman. 1950. |
| Mollard, E. | Ailes naturelles et vol humain. Lib. des Sciences Aéronautiques. 1950. |
| Whittingham, Sir H. | Aviation Medicine. Butterworth. 1950. |
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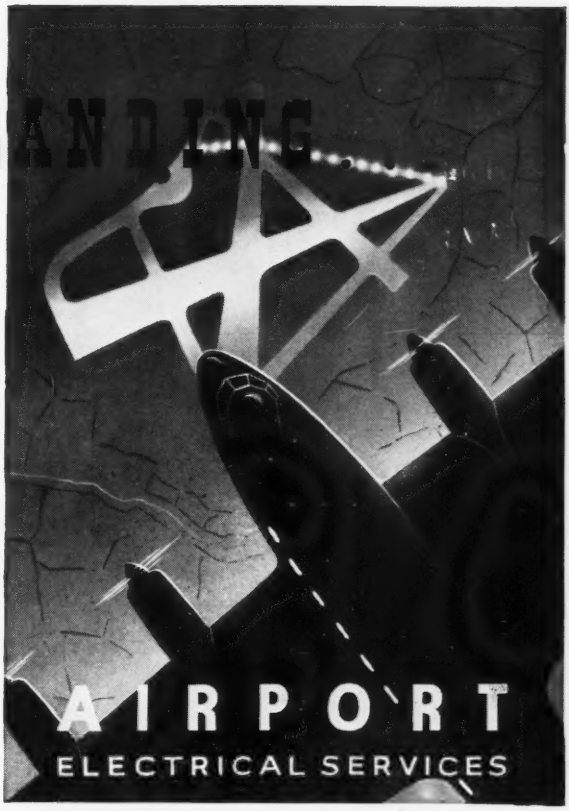


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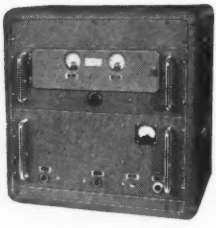

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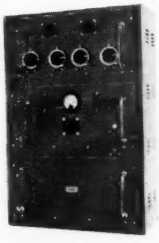

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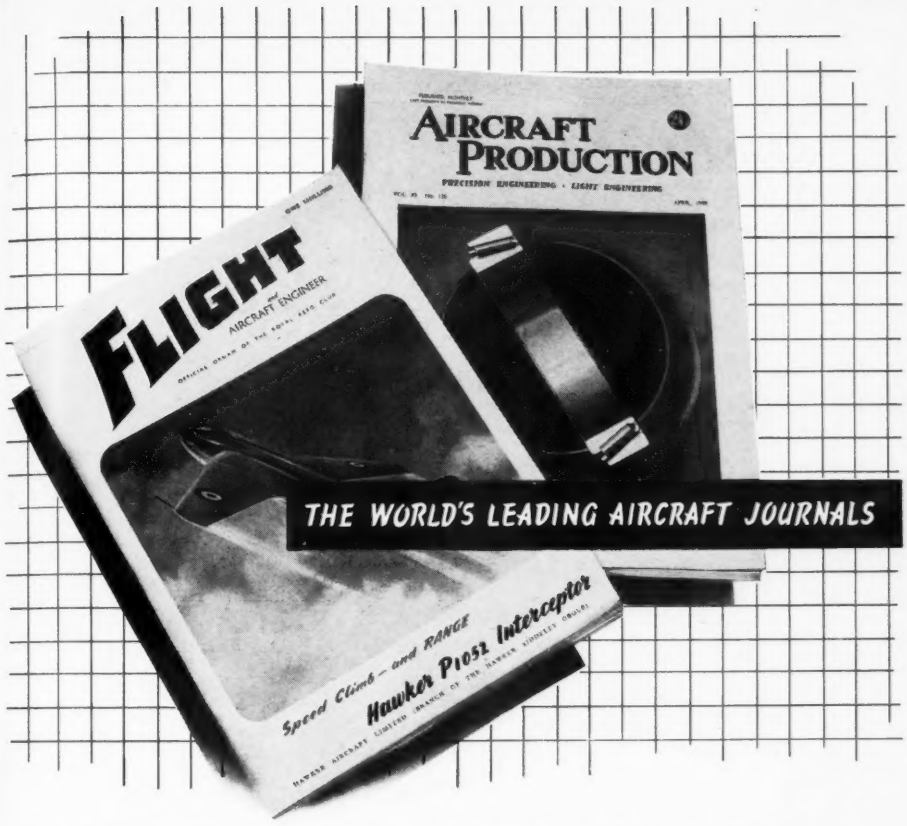


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Sixth British Commonwealth and Empire Lecture

# SOME INTERNATIONAL ASPECTS OF AIR TRANSPORT

by

SIR GEORGE CRIBBETT, K.B.E., C.M.G.

THE Sixth British Commonwealth and Empire Lecture was given before the Royal Aeronautical Society on the 28th September 1950 at the Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, by Sir George Cribbett, K.B.E., C.M.G., on "Some International Aspects of Air Transport."

Before the Lecture, the Silver Medal of the Society, awarded to Mr. W. E. W. Petter, was presented by the President, Major G. P. Bulman, C.B.E., F.R.Ae.S.

**The President:** Two Silver Medals had been awarded by the Society for 1950, one of which, at the Wilbur Wright Lecture, he had handed to the veteran, Joe "Spitfire" Smith; the other was awarded to Mr. Petter, then absent abroad, and it was a pleasure and privilege to present it to him on the present occasion.

Fortunately, Mr. Petter was still in the early afternoon of life; yet his first aircraft, the Westland Lysander, was designed, developed, and brought into production in time to be of considerable use in the early days of the 1939-45 War. Then he had gone ahead with the Westland Whirlwind fighter, and later with the Westland Welkin, neither of which had gone into production, through the changing courses of the war and not because of their lack of quality.

Since the war, with the English Electric Company, he had evolved the Canberra, an aircraft which was believed to be potentially such another classic as were the Spitfire and the Mosquito. Classical aircraft like aero-engines were not created merely by the collection and selection of data, by so many drawing boards competently manned, by adequate machine tool facilities and by slick and efficient organisation, essential as all those were to success. There was something much more to it than that: the creative power and personality of a man; something not fully to be understood except by those who had lived with and through such creative processes. It was no disparagement to the English Electric Company, and to the design team which Mr. Petter had gathered together and inspired and whom he had now left, to say that all through the long history of the Canberra which they hoped to see, advancing through many Marks, they would always think of the Canberra and of Mr. Petter together.

Praise and criticism meant nothing unless they came from people who knew and who had standards from which to judge; uninformed or malicious criticism might well recoil on the utterer; but praise from those who were qualified to understand and appreciate was something very different. And so he believed that Mr. Petter, in receiving the Society's Silver Medal, would value it as much as the Society welcomed the privilege of awarding it to him. In so doing, the Society wished him great happiness in his new surroundings, scope for the exercise of his talents, and increasing ability to satisfy his ambitions. As one who knew him well, he was in no doubt that those ambitions were very simple; to give his uttermost to the advancement of aviation and to his country with every fibre of his being.

He now had pleasure in introducing Sir George Cribbett and inviting him to deliver his lecture. The British Commonwealth and Empire Lectures were inaugurated largely by the inspiration of Mr. G. H. Dowty, F.R.Ae.S., as a counterpart of the Wilbur Wright Lectures, which for some thirty odd years previously had been the outstanding event of the Society's year. In those Wilbur Wright Lectures they commemorated Great Britain's aeronautical associations with the United States of America and normally discussed scientific, technical and military aviation affairs. With the British Commonwealth and Empire Lectures the members of the Society addressed themselves to civil aspects of aviation and more particularly its association with the British Commonwealth. An address was delivered in one year by a lecturer from the Dominions, and in the next year by a lecturer from the home country. Since the Lectures were inaugurated in 1945, there had been lectures by Mr. Hudson Fysh, of Australia—whom the members of the Society were glad to welcome again on the present occasion—by Mr. James T. Bain and by Mr. E. H. Atkin, both of Canada; the home team had comprised Sir Henry Self, Mr. Peter Masefield, and now Sir George Cribbett.

Sir George Cribbett, having served during the First World War initially in the London Regiment, had transferred to the Royal Air Force as a pilot. In 1919 he entered the Civil Service in the Exchequer and Audit Department and had engaged in various Treasury activities, until in 1937 he was transferred to the Air Ministry and became intimately engaged in the civil aspects of flying. From 1941 to 1943 he was Director of the Finance and Administration Division of the Royal Air Force Delegation at Washington, where his services were such as to earn for him the C.M.G. When he came back to Great Britain he was appointed Assistant-Secretary of State at the Air Ministry, with duties largely akin to those of the earlier Director-General of Civil Aviation; and in 1948 he became Deputy Secretary in the Ministry of Civil Aviation. He was Knighted, with the award of the K.B.E., in the same year.

For some years then Sir George had been intimately associated with the international-legal aspects with which his lecture dealt, and he was clearly an enthusiast in such matters.

## 1. INTRODUCTION

In accepting the invitation to address the Royal Aeronautical Society I am deeply conscious of the honour that has been paid to me and of the responsibility I have undertaken. My sense of responsibility flows from the realisation that I have been called upon to contribute from personal knowledge and experience to the great volume of recorded and authoritative opinion already contributed by these lectures.

I have chosen to address you on some international aspects of air transport because it is my firm belief that the lack of an enlightened multilateral code in an important field of international air transport is one of the more serious impediments to the full exploitation of the technical advances with which air transport has been presented in recent years.

The international aspects of air transport, ranging over technical, legal and economic fields, are many and varied, and it would not be possible to do more than touch upon them superficially, if one endeavoured to cover the entire range. I propose, therefore, to confine myself to particular features of international relationships in air transport arising in the economic field. It is in this field of rights to pick up and set down traffic, rates of carriage, subsidies and so on, rather than in the technical and legal fields, that the reconciliation of divergent national views, or the failure to reconcile them, will have the most profound effect on the future development of international air transport. Considerable progress has already been made through the medium of the International Civil Aviation Organisation, established by the Chicago Convention, in securing the multilateral adoption of technical standards and practices which govern the safety of aircraft in operation. The attainment of international objectives in the technical field is in sight, but uniformity of approach, and multilateralism in the

economic field continue to elude their most ardent supporters.

International relations in air transport attract less attention and interest, certainly in Great Britain, than the organisation and operation of our national air transport services. Yet air transport is, by hypothesis, an international economic activity in which every country of standing is either participating or intends to participate. Consequently the basic policies, laws and priniciples now being evolved by the nations of the world must have a determinative influence on the pace and scope of the future development of international air transport. This is a suitable stage, therefore, at which to analyse and review the effects of policies and principles which have influenced post-war air transport development, and to consider future trends.

We are deeply committed to the acceptance of certain basic conceptions which, through a series of international conferences and bilateral agreements, have almost become basic laws of international air transport deeply enshrined in the thinking of all countries now members of the International Civil Aviation Organisation. The doctrine of the freedoms of the air, with its far-reaching implications, which I will describe later, the principle of reciprocity in the exchange of commercial rights, the principle of internationally agreed fares and freight rates as a basis of international competition on scheduled air services, have all become firmly established in our post-war approach to international air transport relations. It is important to realise that there can be no turning back of the clock on these fundamentals which govern the approaches of all countries to their international relations in air transport. Only the complete failure of these basic laws to survive the test of experience could lead to their abandonment or supersession. For better or worse the future course of events in international air transport, so far as one dare predict, seems likely to stem from certain now established concepts.

The particular features of international air transport on which this survey will concentrate are: —

(*a*) exchange of rights of commercial operation — the multilateral and bilateral approaches;

(*b*) the importance and control of regulated fares, freight rates and mail rates;

(*c*) subsidies.

Of these three features, the main emphasis is laid upon the first, but some mention of the other two features is necessary to complete the perspective.

An historical survey of the past and a review of current developments under each of these heads will point to certain unmistakable trends in the coming years. Whatever interpretation one may place on these trends it is clear that we are rapidly approaching a stage when the thinking of all those nations who can contribute to the future success of international air transport is becoming crystallised, for good or ill, in the immediate years ahead.

## 2. EXCHANGE OF RIGHTS OF COMMERCIAL OPERATION

### 2.1. The pre-1939 period

In air transport, as in every other form of economic and trading activity, there is almost universal agreement that commercial rights should be exchanged multilaterally. But multilateral exchange of air transport traffic rights, in the opinion of many qualified judges, is still far from attainment. The far-sighted draftsmen of the Convention for the regulation of Aerial Navigation of 1919, known as the Paris Convention, apparently intended that there should be reasonable freedom to develop international airlines, and that the States adhering to that Convention should impose no unnecessary obstacles on the exercise of traffic rights on the international air routes of the world, other than the right each nation reserves to itself to carry its cabotage traffic, which I will define later. (The United States and the majority of Central and South American countries were not parties to the Paris Convention: they concluded a separate Convention, the Havana Convention of 1928, which was more general and less specific in scope, and was less binding on individual member States.)

Although Article 15 of the Paris Convention permitted any contracting State to make the exercise of traffic rights conditional on its prior authorisation, the intention underlying this condition seems to have been related more to technical and security requirements than to economic considerations. But the ink of the signatures of the Convention was scarcely dry before the multilateral

approach began to give place to bilateral agreements. At the outset these bilateral agreements were confined to arrangements between the signatories and non-signatories to the Convention and were intended primarily to deal with air navigation and other technical provisions of the Convention by which its signatories were bound, so far as practicable, in their relations with non-members as well as members. Later, in the 1920's, there began to appear bilateral agreements exchanging rights to carry traffic on specified routes into and through the territories of the two signatories. When in 1929 a meeting was held in Paris to consider possible amendments of the Paris Convention, the United Kingdom delegation pressed for the most liberal interpretation of Article 15 to permit "unhindered" commercial rights, but the motion was defeated. By this negative vote the growing practice of seeking commercial rights by bilateral negotiations thus received majority endorsement.

Although a considerable number of these bilateral agreements existed before the 1939-45 War, they had not become widespread. Many nations which, at that time, did not aspire to enter the field of international air transport, were still not seriously concerned to formalise the arrangements for granting rights of commercial operation. The rights enjoyed by Imperial Airways in many territories on the Empire routes were not the subject of formal Agreements. Some bilateral agreements were negotiated between Governments, but many more were negotiated between the airlines desiring to exercise the rights and the Government of the territory concerned. Negotiations of this latter class of agreement often imported considerations extraneous to civil aviation as the price of the air transport concessions. Although these agreements were all too frequently difficult to obtain, their form and content were simple. Their main distinguishing features were the designation of the commercial airlines to be granted the rights, the fixing of routes and the invariable provision that any rights granted should be on a basis of complete reciprocity, whether reciprocal rights were to be exercised or not. Some included provisions for agreement on tariffs. There were no complications, except for the reservation of cabotage, in the nature of the traffic rights granted, and the classification of traffic rights in categories of "freedoms," discussed later, had not made its appearance before the 1939-45 War.

In the early years of bilateral agreements establishing the right to operate scheduled services, the chief motive for these agreements seems to have been the desire on the part of many countries to establish beyond dispute, mainly in the context of security, the unassailable rights of sovereignty of each country over the air space above its territory. The theory advanced at Ghent in 1906 at the Institute of International Law, that the air space, like the high seas, should be free to navigation and commerce was discarded on the outbreak of the First World War by belligerent and neutral alike, and the Paris Convention of 1919 established the right to complete and exclusive jurisdiction in the air space above the territory and territorial waters of a State. This basic distinction between the "freedom of the seas" and the limited freedom of the air has made possible, rather than caused, the strict control which every country exercises today over the grant of commercial rights in air transport. For the causes of this strict control we must look in other directions.

While the desire to assert sovereignty, together with fears of security, may have accounted for the early pre-war bilateral agreements, there seems to be evidence that the increasing number of agreements of the immediate pre-war period had their origin in economic causes. By the middle 1920's, it had become increasingly obvious that the infant industry of air transport required considerable subsidy assistance, both in direct payments to operators and in indirect assistance in the provision of aerodromes and ground organisation. The objective of United Kingdom policy of 1920 that civil aviation must fly by itself had become a pious hope. Consequently the freedom to exercise unfettered commercial rights contemplated by the Paris Convention was no longer acceptable to many States, particularly those which had established, or contemplated forming, their own airlines. Where countries A, B, C, and D each sought to exercise commercial rights in each other's territories, the principle of *laisser faire*, with its corollary of the survival of the fittest, could not be accepted by any country, except perhaps the most confident in its ability to achieve ascendancy over the others.

It may well be asked why countries less equipped to engage in international air transport did not postpone their entry into the arena, or if they had entered, retire from it rather than face heavy subsidy charges on

their taxpayers during the period of infancy of the industry. The answer is clearly that all countries with a sense of sovereign and economic consciousness had come to realise that air transport was an instrument of national policy. Major powers regarded air transport, like their mercantile marine, as an important ancillary to national defence. The United States, in the Civil Aeronautics Act, 1938, openly acknowledged the importance of civil air transport to national defence and made provision to subsidise its development from mail revenues. Other countries, unable to maintain a scale of effort to make a significant contribution to their national defence, were impressed with the importance of air transport to the maintenance of their national prestige. No country with important international trading relations could afford to neglect to show its national airline flag.

By 1939 air transport, as an instrument of national policy, had become the dominating factor in determining the economic future of international air transport as a whole. Hence, the growth of bilateralism even before the war, the insistence on strict reciprocity and hard bargaining over route concessions designed to maintain a balance between the realisation of aspirations to expand national air transport systems, and the defence of those systems against competitors supported by subsidy assistance. Most of the long distance air routes of today, spanning oceans and continents, were still in the early stages of development, but international air transport on an intra-continental basis had made rapid strides. In Europe, with its many independent sovereign powers and economic units, the effects of intensive competition among those instruments of national policy were most pronounced. No less than 55 airlines were competing in 1939 for the comparatively small amount of traffic generated in Europe. An average of no less than 60 per cent. of the revenues of these European companies before the war was derived from subsidy and not from traffic.

Thus, when the war began in 1939, the multilateralism of which the Paris Convention visionaries had dreamed, had receded and bilateralism had become firmly established. These bilateral agreements, in spite of the hard bargaining and insistence on strict reciprocity which underlay them, had failed, certainly in Europe, to abate a degree of competition which, in its severity, was inimical to future development.

Unsuccessful attempts had been made during the inter-war years to secure closer international co-operation as a means of rationalising future development in the interests of progress. At the Disarmament Conference in 1932, France, primarily on security but also on economic grounds, proposed the internationalisation of civil air transport under the auspices of a single organisation. Failing a single organisation it was suggested that a number of international organisations should be created so that countries with common interests could be grouped together, each group comprising the countries of a large part of the globe. The countries of Europe, to which Africa and Asia might be added, were cited as an example of a suitable group. These groups were to be styled International Air Transport Unions. Although the French proposal received some support from European countries, Germany and Italy, for reasons which later became apparent, strongly opposed them. The United Kingdom did not oppose the principle of internationalisation but drew attention to the practical difficulties. French influence in favour of a system of international operation was also at work in the Air Transport Co-operation Committee of the League of Nations, but a majority view, including American and British representatives, opposed the proposal. Concurrently, some airlines had voluntarily entered into pooling arrangements which were designed to control competition between them by arrangement of schedules, by pooling and division of all or some revenues, by establishing joint traffic handling arrangements, and by other methods designed to eliminate wasteful effort. These pooling arrangements, however, did not materially reduce the intensity of competition, nor relieve taxpayers appreciably of the burdens which continued to fall upon them.

### 2.2. The War-time and Post-War Phase

During the 1939-45 War international air transport in the eastern hemisphere was virtually extinguished, or at least reduced to negligible proportions. Practically all the major European operating companies ceased operations, and British Overseas Airways was diverted to its wartime tasks mainly in support of the Royal Air Force. Pan American Airways and its various South American associates and subsidiaries were the main regular operators remaining in the field of

international air transport operation. This period was, for them, one of steady expansion which was later to exercise a profound influence on the United States policy towards post-war international air transport.

When the issue of the war was no longer in doubt and the time came for the United Kingdom to consider its policy towards post-war international air transport, it was against a pre-war background of excessive competition in Europe, with its corollary of burdensome subsidies, rate warfare and other unfair competitive devices, and the revival of intense national rivalries, that the various problems were considered. In addition, the atmosphere of war lent great emphasis to future security aspects of air transport development. While there was general agreement that the main objective should be the maximum co-operation designed to secure the elimination of uneconomic competition, different lines of approach to this objective occupied the minds of experts. In some quarters a system of full internationalisation in which all services throughout the world would be controlled and actually operated under the direction of a central authority was favoured. Another school of thought, realising that the success of a single organisation would be dependent on the measure of support it commanded and that many countries of major importance would be opposed to such a system, favoured international ownership and operation on the more limited basis of the French plan, presented at the Disarmament Conference of 1932, of creating a number of regional international groups. The problems of integration of the various internationalised regions and of providing connecting services between them and those States remaining outside an internationalised system were not regarded as insuperable, although it was recognised that the exercise of rights of reciprocal operation between regions might lead to a greater measure of competition on connecting services than would be involved under a plan of full internationalisation under the control of one central authority. The advocates both of the world-wide system of internationalisation and of the regional system, recognised that the participation of all countries in key positions was essential to a realisation of their objectives.

Yet another school of thought believed that any system of international ownership and operation would be complex and unworkable, and would be foredoomed to failure if exposed to competition from major nations which could not be induced to participate. This school of thought believed that international co-operation should be sought by other means which did not involve the subordination of national flags and provided for well ordered competition on the basis of universally accepted principles.

### *The birth of the "Freedoms of the Air"*

It was during this period that United Kingdom thinking turned towards the doctrine of the freedoms of the air which has since secured world-wide acceptance as a basic condition of the exchange of commercial rights. A contemporary official document states that the maximum of co-operation and the elimination of uneconomic competition must involve consideration of the conception of the freedom of the air, which ought not to mean that the aircraft of any country can fly anywhere without any kind of restriction. It ought to mean, states this document, that those countries and aircraft which are prepared to observe certain principles agreed internationally shall not be prevented by other countries from enjoying certain minimum rights essential to operation. The document states that freedom of the air is an undefined term and is variously interpretated as including:—

(1) The right of innocent passage.
(2) The right to land for non-traffic purposes (*e.g.* refuelling, repair, emergency).
(3) The right to land passengers, mails and freight *embarked* in the country of origin of the aircraft.
(4) The right to embark passengers, mails and freight *destined* for the country of origin of the aircraft.
(5) The right to convey passengers, mails and freight between two countries, neither being the country of origin of the aircraft.
(6) The right to convey passengers, mails and freight between two points in any one country not being the country of origin of the aircraft.

Here we have the birth of the analysis of the "freedom of the air" which gave rise to the Five Freedoms as we know them today, and as they appear in practically all international agreements. The Sixth Freedom describes cabotage, which almost every country reserves to its own airlines, and it is commonly known as cabotage, rather than

the Sixth Freedom. With the permission of the author, Mr. Peter Masefield, a graphic illustration of the "Freedoms" appears as Appendix I.

It was generally recognised that the right to pick up and set down traffic, embraced by Freedoms Three, Four and Five, would be conditional on the formulation of satisfactory machinery for regulating competition, but opinion was divided whether the non-traffic Freedoms (One and Two) could be conceded unconditionally. The question was of considerable importance to the United Kingdom, with its far-flung Colonial territories. Many of these territories lay athwart the main trunk routes of the world and were necessary staging points for international airline operation. Consequently they had an important economic value, even though they did not give rise to rights to pick up and set down traffic. The general conclusion was reached, however, that if general support were forthcoming for satisfactory principles of international co-operation, these rights should be exchanged multilaterally and unconditionally.

*United Kingdom policy of 1944*

United Kingdom policy towards international air transport was crystallised and presented in a White Paper, Cmd. 6561 of October 1944, on the eve of the Chicago Conference. As the White Paper states, United Kingdom policy had been formulated after consultation, over a period, with the Governments of other Commonwealth countries which had been considering the general principles which should govern post-war international air transport. It was the object of this policy to eliminate the major evils of the pre-war period, namely that any country on an international air route could hold operators of other countries to ransom, even if those operators only wished to fly over or refuel in its territory; that there was no means of controlling the heavy subsidisation of airlines which all too often were maintained at great cost for reasons mainly of national prestige or as a war potential; and that the bargaining for transit and commercial rights introduced extraneous considerations and gave rise to international jealousies and mistrust. The policy aimed at securing the maximum attainable degree of international co-operation and reaffirmed the United Kingdom belief that "some form of international collaboration will be essential if the air is to be developed in the interests of mankind as a whole, trade served, international understandings fostered and some measure of international security gained." The main objectives of this collaboration were considered to be:—

(1) to meet the needs of the peoples of the world for plentiful, efficient and cheap air services;

(2) to maintain broad equilibrium between the world's air transport capacity and the traffic offering;

(3) to ensure equitable participation by the various countries engaged in international air transport;

(4) to eliminate wasteful competitive practices and, in particular, to control subsidies;

(5) to standardise practice on technical matters important to the safety of flying;

(6) in general, to contribute to world security.

In order to secure these objectives the Government proposed that a new multilateral Convention should be drawn up to take the place both of the Paris Convention of 1919 and of the Havana Convention of 1928, and to make provision for the regulation of international air transport. This Convention was to make provision, among other things, for the following:—

(*i*) re-affirmation of the principle of national sovereignty of the air and definition of what, for this purpose, should constitute the territory of a State;

(*ii*) definition of the degree of freedom of the air to be enjoyed by the ratifying States, conditional on the acceptance in full of the rest of the Convention. Subject to the right of each State to reserve its position in time of war or national emergency, it was proposed that freedom of the air should extend to:—

(*a*) the right of innocent passage through a State's air space;

(*b*) the right to land for non-traffic purposes (refuelling, emergency, etc.);

(*c*) the right to disembark passengers, mails and freight from the country of origin of the aircraft;

(*d*) the right to embark passengers, mails and freight destined for the country of origin of the aircraft.

(*Note*:—The right to pick up and set down traffic to and from destinations which are not in the country of origin of the aircraft and the right to engage in the cabotage of another country would be a matter for negotiation).

(*iii*) definition of the international air routes which should be subject to international regulation; these would be reviewed from time to time as necessary;

(*iv*) provision for the elimination of uneconomic competition by the determination of frequencies (total services of all countries operating on any international route), the distribution of those frequencies between the countries concerned and the fixing of rates of carriage in relation to standards of speed and accommodation;

(*v*) provision for the licensing of international air operators who undertook to observe the Convention and to abide by the rulings of the appropriate authority, and for the withdrawal of the licence in the event of a breach of the obligations;

(*vi*) provision for the denial of facilities to any unlicensed operator;

(*vii*) provision for the collection and review of information about services, costs, subsidies, rates of carriage, landing fees, and so on;

(*viii*) provision for arbitration in matters of dispute;

(*ix*) securing the acceptance by the ratifying States of an obligation to provide, in their respective territories, the ground facilities needed for international services or to allow such facilities to be provided.

The noticeable features of that part of United Kingdom policy which deals with exchange of commercial rights were:—

(1) the renewed attempt to substitute a multilateral exchange of rights in large measure for the welter of pre-war bilateral agreements. The Convention would provide for the multilateral exchange of the first four Freedoms, but would reserve for separate bilateral negotiations the exercise of Fifth Freedom rights, that is, the right to pick up and set down traffic not originated in, or destined for, the State of the nationality of the airline.

(2) The enunciation of the principle of maintaining equilibrium between air transport capacity and traffic offering. Practical effect to the principle would be given by pre-determination of the capacity and frequencies required to meet the estimated traffic potential.

(3) The enunciation of the principle of equitable participation. Effect to this principle would be given by sharing the pre-determined capacity between airlines of nations entitled to compete on an international route scheduled to the Convention, *i.e.* to airlines of those nations with a route terminal in their territory. The basis of sharing of capacity was left for discussion, but equal division or sharing according to the degree of traffic interest was visualised.

It has often been said by commentators on this policy, both at home and abroad, that it was dictated by the desire to secure a measure of protection for British air transport during the period of post-war rehabilitation. The policy, however, was entirely objective and designed to secure orderly development of international air transport and to prevent a relapse into the chaotic pre-war conditions which had become a matter of concern to many civil aviation administrations, particularly in Europe, before the war. There is no doubt that the views of the United Kingdom and many other European countries were strongly influenced by the conditions of intensive competition involving manifest misuse of subsidies and excessively wasteful competition generally in Europe.

*The Chicago Conference 1944*

This was the policy which the United Kingdom delegation, led by Lord Swinton, took to the Chicago Conference of 1944. The United Kingdom was supported in this policy by other Commonwealth countries, but Australia and New Zealand, by a declaration of joint policy, advocated more radical measures. They considered that international ownership and operation, applied at least to the main trunk routes of the world, offered the only economic solution of the future development of international air transport and, at the same time, provided guarantees of future security against misuse of civil air transport.

The failure of the Chicago Conference to find a multilateral solution of the problem

of exchange of commercial rights is now a matter of history. In contrast with the foregoing United Kingdom policy, the United States believed firmly that the development of international air transport with the efficiency necessary to ensure progressive reductions of costs, which would bring its benefits within the reach of an ever widening public, could only be secured by free competition conceived on the basis of complete freedom of the air for all those wishing to participate. Attempts were made to reach a compromise between these opposing viewpoints. The United Kingdom agreed to three major modifications of the policy outlined in the White Paper:—

(1) the grant multilaterally and unconditionally of the right of foreign airlines to fly through the air space and to land for non-traffic purposes (Freedoms One and Two). A multilateral agreement (The International Air Services Transit Agreement) was opened for signature at Chicago and has since come into force to provide for the exchange of transit rights and rights to make non-traffic stops. A country exercising these rights could be required, however, by the country granting the rights to make stops for traffic purposes.

(2) Agreement to exchange Fifth Freedom rights on a multilateral basis, subject to certain conditions, instead of reserving them for bilateral negotiations as proposed in the original British plan.

(3) The qualification of the provision for the division of capacity equally, or according to traffic interest, by a supplementary provision which allowed an operator, who succeeded in attracting the traffic, to increase his share of capacity within certain limits, short of extinguishing his competitors. This was described at the time as provision for "escalation."

Although these concessions to the United States viewpoint appeared, at first sight, to provide a possible basis of compromise, prolonged examination of the practical application in detail of these modifications under a system which involved *a priori* determination of capacity and frequencies, failed to bridge the gap. The failure has been ascribed to various causes between the extreme view of a United States policy based on an aggressive bid for supremacy in air transport, and a United Kingdom policy springing from motives of self-protection during a difficult period of post-war readjustment. My own view is that none of these explanations accurately represents the position of the main protagonists.

The United States had witnessed the steady expansion of a prosperous domestic air transport system, based on a regulatory system of licensing administered by the Civil Aeronautics Board. In the international field their main pre-war and war-time activities had extended southwards to Latin America, where they encountered little competition and air transport was welcomed by most of these countries for the benefits it conferred on communities inadequately served by surface transport. They were, undoubtedly, inclined to interpret the requirements of world-wide international air transport in the light of their own experience in Central and South America, but they failed to recognise that the British plan was intended to be the international counterpart of the regulatory system they had found necessary to control their own domestic air transport development.

Where every sovereign power is free to engage in competitive international air transport, control through a licensing system is virtually impossible and some other means of securing rational and well-ordered development must be found through international co-operation based on sound principles. The United Kingdom, as has already been stated, were profoundly influenced in their approach by the chaotic conditions in pre-war Europe, and they foresaw that unless some satisfactory regulatory system were introduced before post-war competition began, the pre-war conditions of Europe would tend to spread throughout the world.

Although the Chicago Conference failed to produce a universally acceptable multilateral agreement to govern the exchange of commercial rights in international air transport, the United States tabled for signature a multilateral agreement providing for the unqualified exchange of all five Freedoms. This agreement found little support and it came to an abrupt end in 1946. The Chicago Conference then left nations with no choice but to fall back on bilateral agreements to secure rights of operation. Initially, both the United States and the United Kingdom reverted to their pre-Chicago policies in the negotiation of bilateral agreements. United States agreements with Spain, Ireland, Scandinavia and

a few other countries were concluded on the basis of complete freedom of the air, while United Kingdom agreements made provision for maintaining equilibrium between capacity and traffic offering, for the pre-determination of the capacity and its division between the airlines of the two signatories of the bilateral agreement, and for the exercise of Fifth Freedom rights on the basis advocated by the United Kingdom at Chicago. Agreements of this type were concluded with Portugal, Greece, Canada, Turkey and France (for services between metropolitan territories only).

*The Bermuda Agreement*

It was not long before these widely different approaches to bilateral agreements began to create difficulties. The same countries approached by the United States and the United Kingdom were perplexed by these divergent policies and hesitated to conclude bilateral agreements. Matters came to a head when United States airlines sought to expand their North Atlantic services to Europe via London beyond the two frequencies a week permitted to Pan American Airways under a bilateral agreement of 1937. Thus, the unresolved controversy of Chicago in the multilateral context was now translated into the bilateral field of negotiations between the United States and the United Kingdom. Delegates from the two countries met at Bermuda in January 1946, and signed an Agreement on the 11th February. This Agreement was a triumph of compromise and has had far-reaching effects on the subsequent course of development of international air transport in which the United States, the United Kingdom and many other countries are involved. The nature of this compromise was described by the then Minister of Civil Aviation, Lord Winster, in the following terms:

> "The Agreements just concluded between the United States and this country at Bermuda represent an achievement satisfactory to both countries. The desire of the United States, on the one hand, to avoid regulation which might be construed as restrictive of exploiting the potentialities of air transport to the full and the desire of the United Kingdom on the other hand, to ensure that international air services are developed on an orderly basis which will eliminate wasteful competition and uneconomic subsidies have been reconciled. The United States Government have agreed that all fares on air services of mutual interest to the two countries should form the subject of agreement, and this they propose to achieve in two stages. First, they have agreed to recognise for a period of one year the status of the International Air Transport Association, an international organisation representative of operators, as a rate-fixing body acting through their various rate conferences. They have also undertaken to seek legislation from Congress which will empower the Civil Aeronautics Board to control rates. This is, in itself, a considerable advance on the position which confronted us before the Bermuda Conference began.
>
> "As regards the control of capacity operated on the routes, it has been recognised that pre-determination on the basis of estimated traffic potentials is beset with practical difficulties and instead, it has been agreed that the principle for which we stand, namely the maintenance of a close relationship between capacity operated on the various routes of mutual interest and traffic offering, can best be put into practical effect by providing for an *ex post facto* review on the basis of this principle. Machinery for close and continuing collaboration between the two Governments will be established to this end."

It has been freely stated by critics on both sides of the Atlantic that each surrendered its principles to the other. The truth lies, as it so often does in matters of this kind, in the fact that the Bermuda Agreement was satisfactory to both the parties that had negotiated it. The main difference of substance between the United Kingdom final plan advocated at Chicago and the Bermuda Agreement is that capacity, frequencies and associated matters are subject, in relation to a virtually common code of principles, to *ex post facto* review instead of *a priori* determination. At Chicago the United Kingdom advocated the pre-determination of capacity necessary to meet the estimated traffic potential and the division of this capacity equally between the two countries entitled to carry Third and Fourth Freedom traffic, subject to the escalator provision which allowed the operator who attracted the traffic to increase his capacity, within defined limits, to meet the public demand. One of our difficulties was to fix a constant load factor to determine the point at which escalation might com-

mence. A fixed load factor of universal application, irrespective of the route or conditions of operation, would clearly give rise to anomalies. The point at which an operator is turning away traffic must vary from route to route and according to conditions, and the only true criterion is the actual turning away of traffic at the booking office of the operator. On the London-Paris route, for example, on which British European Airways and Air France operate an hourly service, the traffic is heavy at certain peak hours and lighter at other times. To cater for this peak traffic it may be necessary to duplicate the services at peak hours, without taking off the more lightly loaded services which constitute the frequency of service to the public and on which the success of the whole operation must depend. In such a case the average load factor over all the services may only be 70 per cent.; yet an increase of capacity on peak hour services is justified in order to satisfy public demand.

Consequently in the Bermuda Agreement the escalator provision of Chicago was substituted by the more practical and flexible principle of "fair and equal opportunity" provided that the services of one airline do not affect unduly the services of the other. As an overall safeguard against inflation of capacity, the Bermuda Agreement adopted the principle of maintaining a reasonable relationship between the combined capacity of the operators and the total traffic, in substitution for the principle of equilibrium forming part of the United Kingdom plan at Chicago.

On the vexed question of Fifth Freedom, there was general recognition at Chicago that Fifth Freedom must be combined with Third and Fourth Freedoms as part of the one and indivisible problem of capacity. The British approach at Chicago to provision for the Fifth Freedom element was a complicated application of the principle of tapering capacity, the farther the aircraft travelled from its home base. The theory was that Fifth Freedom could only be allowed within the available margin of capacity incidental to the provision of the capacity necessary to carry Third and Fourth Freedom traffic. Obviously the farther the aircraft moves from its home base the Third and Fourth Freedom traffic declines and, in the absence of a tapering of capacity, there must be greater dependence on Fifth Freedom to maintain loads.

An attempt was made to assess this tapering capacity by dividing the routes into long sectors and applying to each sector an arbitrary formula which might, or might not, bear a relation to the public demand. But this elaborate method ignored the fact that very few routes presented the same problem. On certain routes intermediate countries had no long distance services of their own, but the principle of tapering capacity by restricting the Fifth Freedom margin would have denied the right of these intermediate countries to travel by air. Almost alone this seemed to condemn the principle of tapering capacity for universal application. As a result an attempt was made in the final British plan at Chicago to produce flexible rules which would reconcile sometimes conflicting interests without stultifying air transport development and denying the public the services to which they were entitled. These rules are of sufficient interest and significance to repeat. Fifth Freedom capacity will be related to:—

(1) The capacity which the State is entitled to operate to carry Third and Fourth Freedom traffic.
(2) The needs of the division (*i.e.* sector of route) for air transport, judged in relation to public convenience and necessity.
(3) The position of regional and local air transport development.
(4) Economy of through airline operation.

The corresponding provisions of the Bermuda Agreement which govern the determination of Fifth Freedom read as follows:

"It is the understanding of both Governments that services provided by a designated air carrier under the Agreement and its Annex shall retain as their primary objective the provision of capacity adequate to the traffic demands between the country of which such air carrier is a national and the country of ultimate destination of the traffic. The right to embark or disembark on such services international *traffic destined for and coming from third countries** at a point or points on the routes specified in the Annex to the Agreement shall be applied in accordance with the general principles of orderly development to which both Governments subscribe and shall be subject to the general principle that capacity should be related:—

*Author's subsequent italics.

(*a*) to traffic requirements between the country of origin and the countries of destination;

(*b*) to the requirements of through airline operation; and

(*c*) to the traffic requirements of the areas through which the airline passes after taking account of local and regional services."

The close resemblance between the Chicago and Bermuda provisions for Fifth Freedom will be apparent. From this analysis of the main features of the British final plan at Chicago and the Bermuda Agreement, it will be seen that the basic principles remained. The need for relating combined capacity of competing airlines to total traffic is still a recognised first principle. Another principle makes the Third and Fourth Freedom capacity requirements the foundation of the services. Yet another is the need for giving protection to local airlines and the holding of the balance between them and through airlines.

But the indefensible fixed load factor for determining the relationship between capacity and traffic in the Chicago plan gave place in the Bermuda Agreement to the reasonable load factor to be interpreted according to route and circumstances. The difficult escalation provisions of Chicago, to allow the operator whose services are in public demand to increase his capacity within reasonable limits, have given place to the practical principle of fair and equal opportunity, while at the same time guarding against inflation of capacity and operation unduly detrimental to the competing airlines. Attempts to determine Fifth Freedom by formula, as originally advocated at Chicago, were supplanted both in the final British plan at Chicago and in the Bermuda Agreement, by similar flexible principles which can be applied to any set of circumstances in a fair and equitable manner.

Thus the Bermuda Agreement translated into practical form the code of principles which the United Kingdom regarded as necessary to secure well ordered development among competing national airlines. It gives freedom to airlines to adjust requirements to meet the traffic demand, in accordance with a code of sound principles, and provides machinery to rectify abuses of this freedom in the form of unfair or uncommercial practices or attempts to impinge unduly on the legitimate minimum rights of the other party. In addition to the general principles relating to the exercise of the Five Freedoms, and the associated capacity provisions, the Agreement provides that fares and freight rates should be subject to agreement, initially through the medium of the Airline Operators' Conferences of the International Air Transport Association, which had been established at Havana in 1944 and represents the world's principal airline operators. The routes along which the rights were to be exercised by United Kingdom and American airlines respectively were scheduled to the Agreement. The determination of the path of the routes and the numbers of routes themselves are important features of these agreements. Indeed, the whole elaborate mechanism of capacity control and agreed rates can be brought to naught unless the routes on which the rights can be exercised are defined. The route pattern in international exchanges of rights is of such importance that the United Kingdom and United States Governments have always regarded it as essential to reserve the negotiation of routes for separate bilateral treatment in all discussions of a multilateral agreement.

The Bermuda Agreement not only resolved outstanding differences between the United Kingdom and the United States, but it appeared to constitute a landmark in international air transport history. It seemed to possess all the ingredients, suitably adapted, for a multilateral agreement to which all countries desiring to see international air transport develop on a well ordered basis, subject to checks on abuses, could subscribe. Both the United States and the United Kingdom delegates attending the meeting of the Assembly of the Provisional International Civil Aviation Organisation in May 1946, stated that the principles of the Bermuda Agreement were considered to provide a satisfactory approach to a multilateral agreement which was always their objective. Later in the same year, the two countries agreed that, pending the adoption of a multilateral agreement, the Bermuda type of agreement represented the best form of approach to the negotiation of interim bilateral agreements and that they would be willing, at the request of any Government, to revise extant agreements which were deemed to depart from Bermuda principles.

During 1946/47, the Air Transport Committee of the Council of P.I.C.A.O. was set the task of drafting a multilateral agreement for the consideration of a subsequent

Assembly. This Committee was divided in its conclusions and produced majority and minority reports. The majority report was signed by Canada, France, the Netherlands and Iraq, and the minority report by the United States, the United Kingdom and China. It is not necessary to describe the provisions of the report in detail, but the main differences between the majority and minority views arose over the question of freedom to operate routes—the majority view—and the reservation of routes for bilateral negotiation —the minority view—and differences of treatment of the controversial issue of the Fifth Freedom.

*Multilateral Commission of I.C.A.O.—Meeting at Geneva 1947*

In the subsequent discussion at the first meeting of the Assembly of the International Civil Aviation Organisation in May/June 1947, the differences outstanding appeared to have been sufficiently narrowed down to encourage the belief that a Special Commission of I.C.A.O. might be held later in the year to draft a multilateral convention, with every prospect of success. The Commission met at Geneva in November 1947, and after a preliminary study of post-war traffic statistics of airline operation, got down to its main task. A serious difficulty, however, arose at the outset. In an endeavour to facilitate settlement of the hitherto intractable problem of Fifth Freedom, the Canadian delegation proposed that only the first four Freedoms should be exchanged multilaterally, leaving the Fifth Freedom to be negotiated bilaterally in accordance with certain defined principles on the lines of the corresponding provisions of the Bermuda Agreement. This approach, which commanded some support, particularly among countries whose airlines had not yet become established, was in essence a reversion to the original United Kingdom plan published in White Paper, 6561, of October 1944, as a basis of United Kingdom advocacy at the Chicago Conference. But, as has already been mentioned, the segregation of the Fifth Freedom was abandoned by the United Kingdom and her supporters at a very early stage of the Chicago Conference. We had accepted the view that, for the purposes of any multilateral agreement, the Fifth Freedom was part of the one and indivisible problem of capacity. The revival of the proposal to deal bilaterally with Fifth Freedom was unexpected. Although Fifth Freedom had been the centre of many discussions since Chicago, the question of segregating Fifth Freedom traffic from Third and Fourth Freedom traffic had not been raised during the post-Chicago period.

Accordingly, the United Kingdom and the United States sought to set aside the Canadian proposal. Their advocacy was designed to show that long distance airline operation, involving forward orders for equipment and other preparations for the accompanying scale of effort, could not be planned ahead on a basis of a known volume of end to end traffic while leaving intermediate Fifth Freedom traffic to the uncertainties of bilateral negotiation, which might defeat economic through-airline operation.

Although the doubts of many supporters of the Canadian approach were not allayed by the arguments of the United Kingdom and the United States and their supporters, it was finally agreed to discuss a multilateral agreement based on the premise that the five Freedoms would be exchanged multilaterally, leaving only the route patterns to be negotiated on a bilateral basis. Opinion was divided on the necessity for reserving route patterns for bilateral treatment, but the United Kingdom considered that a stage had not yet been reached when these could be left to multilateral choice. The United Kingdom, however, proposed a number of basic principles which all countries would undertake to observe in the negotiation of bilateral route agreements.

After some discussion of the elements of a capacity control clause which would govern the exercise of the commercial Freedoms (Third, Fourth and Fifth) a working group, comprising representatives of the United States, Canada, France and the United Kingdom, was formed to draft a capacity clause. When this clause was debated in full Commission, a clash of views became manifest between the nations interested in long distance airline operation and those engaging in local and regional services. It would be idle to minimise the real difficulty in attempting to hold the balance fairly between the long-stage trunk route operator, catering for long distance traffic, and the short-range operator, catering for local and regional traffic. Obviously there is a public need for both classes of operation. The long distance operator, however, could not fulfil, on an economic basis, his contribution to international air transport development without rights to pick up and set down traffic arising

at intermediate points. The short-range operator, on the other hand, feared that his operations would be threatened unless severe restrictions were imposed on the through operator to carry intermediate local and regional traffic. Eventually a clause, amended in Commission in the endeavour to reconcile these dual requirements, was passed by a narrow majority to the expert Drafting Committee. A copy of this clause is given as Appendix II.

The Conference then discussed clauses for controlling fares and freight rates and for the settlement of disputes. Considerable progress was made with these clauses. Fares and freight rates were to be determined with due regard to costs, profit and standards of service, and agreed between the airlines through the medium of the International Air Transport Association and to be subject to approval by Governments. Disputes were to be settled by arbitration, either through the International Court or a specially appointed Arbitral Tribunal, all nations agreeing to accept decisions as binding.

But when the capacity clause, on its return to the Commission from the Drafting Committee, was opened to debate an unexpected motion was made which sought to remove Fifth Freedom from the multilateral agreement and to substitute in the proposed bilateral route agreements, the right to contract out of Fifth Freedom. Equally unexpectedly, the associated resolution which was tabled by Mexico, was passed, 12 nations voting in favour, 9 against and 5 abstaining from voting.

The practical effect of this resolution was to restore the original Canadian proposal to exchange Third and Fourth Freedom rights multilaterally, leaving the Fifth Freedom to bilateral negotiation. No country interested in long distance trunk route operation could go forward on a basis which gave no assurances of sound commercial development, facing the prospect of encountering artificial barriers raised at key points by countries opposed to the grant of Fifth Freedom rights. Thus, another attempt to secure a multilateral agreement for the exchange of commercial rights had failed on the vexed issue of the exercise of the Fifth Freedom.

*The post-Geneva situation*

Consequently the routeing of international air transport services and the nature of the commercial rights to be exercised on the routes continue to be governed by bilateral exchanges. The United Kingdom, in their negotiations with other countries, endeavour to conform to the essential features of the Bermuda Agreement pattern in the belief that this type of agreement is the best yet evolved to give practical expression to a policy of progressive expansion in international air transport, while holding the balance between the needs of the public both for long distance air transport and for local and regional services. But the loss of flexibility, which is inherent in bilateralism, is aggravated by the growth of national policies of self-protection, which lead to restrictions both on the routeing of the services and on the grant of Fifth Freedom rights on long distance operations. Just as every country with a seaboard sought to play a part in international shipping after the First World War, so every country of substance decided to develop its air transport following the Second World War. Over 50 countries (excluding dependent territories) are now engaged in international air transport operation, ranging from local links with adjacent territories to long distance trunk operations.

Technical progress with transport aircraft development, combined with the extensive scale on which air transport was employed during the 1939-45 War, may have led many countries to believe that the age of profitable commercial air transport had arrived. The all-important factor of national prestige, no doubt, also played a conspicuous part in deciding many countries to engage in this new form of transport enterprise.

It must now be evident, from the experience of the past five years, that international air transport has not yet reached a stage of economic self-sufficiency and that many countries could obtain the benefits of air transport at far less cost to their taxpayers if they relied upon the services of those countries which are far better equipped technically and economically to provide them as part of wider systems of development. It is wishful thinking, however, to expect a country, once committed to participate in air transport development, to subordinate national prestige to the natural laws of economics. Consequently, national prestige, with its corollary of reciprocal rights for any rights granted, dominates, as it did before the 1939-45 War, this phase in the evolution of international air transport.

This phase of international air transport development is bedevilled by two main

factors, namely (*i*) the failure of air traffic to live up to expectations of progressive post-war expansion. There has been substantial expansion, but even the more conservative prophets have under-rated the persistence of the war aftermath with its legacy of unsettled world conditions, currency restrictions and rising costs. (*ii*) the determination of practically all sovereign powers to participate in international air transport. This has led to the provision of capacity to meet a traffic demand which present world economic conditions and current levels of fares and rates for other traffics cannot sustain.

Some of these problems are temporary. The traffic potential is susceptible of great expansion, both by the creation of new classes of traffic, which air transport will generate, and by transfer from other forms of transport. Today less than 20 per cent. of the yearly traffic moving between the United Kingdom and France travels by air. Whatever differences of opinion may exist about the relative attractions and consequent patronage of air and sea travel on the North Atlantic, it is inconceivable that the physical and other advantages of air travel over surface transport between the United Kingdom and the Continent will not ultimately secure to air transport a much greater share of this traffic. The limiting factors, at present, are fare levels and a public which has not yet become air-minded. But with the design of aircraft of progressively improving economic performances and with a rising generation attuned to the air age, these limiting factors will be steadily removed. Improvements in world economic conditions and general trade revival are more difficult to predict but, given a period of stability and freedom from war, it is reasonable to assume a progressive improvement of world economic conditions, and the removal of existing restraints.

But this belongs to the future. Meanwhile, we have with us the interim problems of a sluggish traffic potential, too many competing interests and conditions of economic abnormality. Hence, the growth of national self-protection on the part of countries which have not yet established themselves in international air transport. The influence of national airlines on their Governments in pursuing protective policies is becoming clearly discernible. It is natural that airlines, charged with the difficult task of justifying their commercial results in this highly competitive field, will strive for protection at home and opportunity overseas, but Governments in the discharge of their wider policy responsibilities for promoting efficient and economical expansion of international air transport, must retain a proper perspective and be on their guard against the erection of barriers to defend inefficiency. Extreme protectionism and unreasonable restrictions on the exercise of commercial rights must retard the expansion which, itself, can set in motion the continuing cycle of reducing costs and fares and the consequent growth of the traffic demand.

The economics of international air transport development and the purses of national exchequers will be severely strained during the next few years unless insistence on the principle of reciprocity, which normally takes the practical form of expensive competition between independent national airlines operating in parallel over the routes which join their territories, can be tempered by some form of rationalisation. It may be that the trend towards closer international economic co-operation in other fields will find its reflection in air transport, but national sovereignty and national prestige considerations still exert a profound influence towards independence in this field.

*Forms of Commonwealth co-operation*

In the British Commonwealth, we have set many examples in the past of economic co-operation without sacrifice of prestige or independence. We have already made some progress in forms of Commonwealth co-operation in air transport development with the object of minimising, or eliminating, wasteful effort. Considerations of prestige and independence have not prevented Australia, New Zealand and the United Kingdom from taking the rational step of combining their interests in the tripartite airlines British Commonwealth Pacific Airlines and Tasman Empire Airways to operate services on behalf of the three countries on the trans-Pacific and trans-Tasman routes. The airlines of Australia and the United Kingdom, and of South Africa and the United Kingdom, operate under partnership arrangements on the Kangaroo and Springbok routes. The essence of these partnerships is to eliminate duplication of aircraft and traffic handling facilities on the routes, to permit scheduling of services in the public interest and to avoid inflation of capacity beyond the needs of the traffic by adopting the simple incentive of

pooling revenues and distributing them in proportion to the effort which each partner contributes. The maximum advantages of this type of partnership, which is merely a peculiar Commonwealth variant of "pooling," are secured under the Australia-United Kingdom partnership where the same type of aircraft is used by both partners.

Yet another example of Commonwealth co-operation is the division of responsibility between trunk route operators, regional operators and local operators for the provision of air transport services linking British territories in Southern Africa. Under the aegis of the Southern Africa Air Transport Council, the responsibility for providing long stage services connecting British territories in Southern Africa has been assigned to the trunk route operators (British Overseas Airways Corporation and South African Airways), while the responsibility for shorter stage services which do not compete directly with the long stage services on the trunk route, is assigned to regional operators and the purely local services within the separate British territories are the preserve of the local short distance airlines. This form of rationalisation merely assigns to the several types of operator the class of operation for which they are most suited, and so avoids duplication of effort and wasteful competition.

Thus, within the Commonwealth, we can point to examples of three different forms of international co-operation, namely, joint ownership and operation, parallel partnership or "pooling" operations, and rationalisation by division of responsibilities between operators who might otherwise compete unnecessarily. There is still scope within the Commonwealth for further application of policies of co-operation, particularly between the United Kingdom and the various Colonies and between groups of Colonies themselves. In the Far East, the Mediterranean and elsewhere, there exists overprovision of local airlines which, in turn, may duplicate the long distance Imperial communications provided by the trunk route operators. The significant point is that within the Commonwealth we have addressed ourselves not unsuccessfully to forms of international co-operation which are designed to provide a rightful share for all participants, according to their resources and responsibilities, and, at the same time, to eliminate avoidable duplication and wasteful features of competition. There are lessons to be learnt from these experiments for much wider application during the difficult years that lie immediately ahead.

Admittedly, it would be more difficult to apply these solutions in the broader international field against the forces of national sovereignty and prestige. Nevertheless, it is in the direction of constructive measures of international co-operation, rather than in policies of self-protection and restrictionism, which only stultify development, that we must look not only for solutions of the problems of this interim period, but also for laying the foundations for speeding up the momentum towards the future prosperity which is within the reach of international air transport.

## 3. FARES, FREIGHT RATES AND MAIL RATES

### 3.1. Historical

The systematic and world-wide fixing of standard fares and freight rates, as a basis of international air transport competition, is of post-war origin. Prior to 1939 there was no general policy, commanding universal acceptance, of determining standard fares and freight rates for the various routes over which competing national airlines operated. The airline operators of Europe had formed in 1919 the International Air Traffic Association "with a view to co-operate to mutual advantage in preparing and organising international aerial traffic." This body began with a membership of six airlines comprising United Kingdom, Danish, Norwegian, Swedish, Dutch and German interests and by 1939 had grown to a membership of 29 companies comprising all major European operators and a few companies from the western hemisphere. Pan American Airways were elected to membership in September 1939, but the war overtook their active participation. The pre-war International Air Traffic Association did much valuable work in securing uniformity of procedure and documentation relating to traffic handling, technical standardisation and codification of international air law governing the liabilities of operators. But their evolution had not progressed far enough to exert any general influence over fares and freight rates, with which this survey deals, and it is with their successor, the post-war International Air Transport Association, of world-wide membership, that we are most concerned on this

aspect of international air transport development.

It is true that some pre-war bilateral Agreements dealing with the exchange of commercial rights made provision for agreed fares as a basis of reciprocal operation of the airlines of the two parties, and that agreed fares found their place in pre-war pooling arrangements between certain European countries. In general, however, the principle of the standard fare, by which all competing operators on a route would be bound, is a post-war development.

### 3.2. United Kingdom policy

The United Kingdom, in its declaration of post-war policy towards international air transport in the White Paper Command 6561 of October 1944, laid great stress on the need for the adoption of fixed rates of carriage, in relation to standards of speed and accommodation, as a basis of orderly development of post-war international air transport. The elimination of the evils of pre-war rate cutting, with its corollary of subsidy warfare, was regarded as a matter of primary importance. Indeed, a contemporary British economist of world-wide fame held the view that the elimination of rate cutting, unjustified by economic costs and fed by subsidies, and the fixing of standard rates of carriage by reference to economic costs, were the most important factors on which to concentrate in securing orderly development of international air transport.

United Kingdom policy also favoured settlement of rates of carriage between airlines, on lines analogous to the long-established Liner Conferences which function for shipping rates. In view of the close connection between rates of air carriage and subsidies, of which the industry still stood in need, it was thought that the rates agreed between operators should be subject to the approval of Governments.

At the Chicago Conference of 1944 there was universal acceptance of the principle of agreed rates, but some doubt existed in the minds of the United States delegation whether the establishment of an international body charged with rate-fixing functions could be reconciled with the powers of the Civil Aeronautics Board and certain constitutional limitations. This particular difficulty was later resolved in the Bermuda Agreement in which the United States agreed to approve the rate conference machinery of the International Air Transport Association for a period of one year. This approval has since been renewed and may now be regarded as well established.

### 3.3. Formation of International Air Transport Association and its functions as a rate-fixing body

The favourable reception by the Chicago Conference of the policy of agreed rates of carriage led to a decision among the principals of the world's airlines, who were attending the Chicago Conference as advisers to their Governments, to convene a meeting immediately following the Chicago Conference. The meeting was held at Chicago in December 1944, under the Chairmanship of Mr. H. J. Symington, then President of Trans-Canada Airlines, and a Committee was appointed under the Chairmanship of Mr. John Cooper to draft articles of association for a new and world-wide organisation covering the functions of the pre-war International Air Traffic Association and with wider responsibilities, including rate-fixing. The new I.A.T.A. was duly established in the following April at a Conference held at Havana and attended by the representatives of the airlines of 31 nations. Its membership now comprises more than 70 airlines representing more than 40 countries. With its headquarters at Montreal, under the same roof as I.C.A.O., I.A.TA.. has a permanent staff, with Sir William Hildred the Director-General as its head. It has an Executive Committee of 12 members which directs the policy of the organisation and its functions are administered within the framework of four Standing Committees—Financial, Legal, Technical and Traffic. The achievements of I.A.T.A. within the five years of its existence have been remarkable in all its fields of activity, but in the context of this survey, our interest is mainly focused on its rate-fixing work under the general aegis of the Traffic Committee.

Among its other responsibilities I.A.T.A. is charged with obtaining agreement on rates and matters affecting rates, such as commission paid to agents. This responsibility is discharged through the medium of Traffic Conferences which meet twice a year. In the early stages of I.A.T.A. the international air transport world was divided into seven Traffic Conference areas but the number was

reduced to three in 1947. These Traffic Conferences are open to any member operator with an interest in the rates determined for the various routes in the area. It will be obvious that many routes traverse more than one area and that there must be close co-ordination of inter-related and inter-dependent rates. The decisions of the Conferences are promulgated in the form of Resolutions, which can only be passed by unanimous vote. The Resolutions are then subject to the approval of Governments.

Through the machinery of the Traffic Conferences standard rates have been fixed for the majority, but not all, of the world's main air routes. This machinery has functioned with reasonable satisfaction and has achieved its primary object of avoiding rate cutting on the normal operations of competing airlines on the main trunk routes. Nevertheless, the organisation has been subjected to the natural stresses and strains to be expected in reconciling the views of its 70 members. Experience has proved the soundness of the basic conception that the initial responsibility for rate-fixing should rest with the operators, who are answerable for their commercial results. It is also important that Governments should retain their power to approve or disapprove rates, as trustees for the public, both as users of transport and as taxpayers with an actual, or contingent, liability for subsidies.

The outside observer, however, may well ask whether or not there are directions in which the machinery could be improved. The rule of unanimity governing Rate Resolutions for example, has occasionally led to difficult situations and undoubtedly allows an irresponsible exercise of the power of veto. This rule often results in Conferences being unduly protracted, in unsatisfactory compromises as a basis of Resolutions, and in ambiguous wording of Resolutions as the only basis on which general agreement can be obtained. Neither compromise nor ambiguity is satisfactory, especially if it should lead to attempts at unfair exploitation on the part of a particular airline or airlines. One is accordingly tempted to pose the question whether Resolutions should not be passed by high majority votes, which have been found satisfactory in other international organisations. One objection which is sometimes raised to the high majority vote is the problem of dealing with a recalcitrant minority, which may comprise powerful airlines, but it should be borne in mind that all inter-Government bilateral Agreements make provision for agreed fares as a basis of the exercise of the commercial rights they confer and consequently, the ultimate power rests with a Government party to a bilateral Agreement to refuse commercial rights to any airline which may seek to undercut a rate to which other members of a Traffic Conference may be prepared to subscribe. Equally, even under the existing unanimity rule, it is open to any Government to refuse to approve a Resolution and, thus, render it ineffective.

There are also the problems of the converse position in which a progressive minority of airlines, with complete economic justification, may seek to introduce reduced fares for special classes of travel, such as tourist traffic. A less efficient, or less prepared, majority may defeat, or certainly postpone, such attempts to increase the potential of international air transport by bringing it within the reach of a wider public. Such penalties of majority rule in international organisations, provided they do not amount to serious impediments to progress, must be accepted as the price of the wider advantages obtained. In the last analysis Governments should be prepared to bring pressure to bear upon their airlines, especially where they rely on subsidy support, in order to prevent abuses of majority rule becoming barriers to economic progress.

Another handicap to the effectiveness of the work of I.A.T.A. is the length of time taken by some Governments to reach decisions on Resolutions affecting rates. I.A.T.A., in its attempts to overcome these delays, has endeavoured to prescribe, in agreement with Governments, fixed periods within which their Resolutions should be regarded as effective. But this has not prevented certain Governments from intimating during the interval that the rate cannot be regarded as approved pending further consideration. Fortunately there are few Governments which offend in this respect but if the bad example they set should be followed by others, the rate-fixing machinery may fail owing to the impossibility of securing the agreement of some 40 countries.

Over the post-war period there has been a certain fluctuation in fare levels, with no marked overall trend either upwards or downwards. As the industry developed and grew in experience one might have expected fares to fall for these reasons and to promote expansion of the industry. For a time after

the war there was a slight downward tendency, but the continuing rise in world prices has arrested, and even slightly reversed, this trend. Revaluation of sterling and linked currencies in September 1949, raised dollar costs to most European operators and reduced the dollar revenue from fares in Europe and eastwards (which are based on sterling) to the Americans.

North Atlantic fares figure prominently in the world fare structure and it is interesting to note that the airlines are now recommending a return to the level ruling in August 1946. In that month the London-New York fare was $375; in December 1946 it dropped to $325, rose in the middle of 1948 to $350 and has remained there since. At their recent Conference in Madrid the International Air Transport Association have proposed that in October 1950 it should return to $375.

There are no pre-war North Atlantic fares with which to compare these post-war figures, but if we take representative fares in the old world we find that the pre-war London-Paris fare of £4 10s. has risen to £8, while the London-Singapore fare has increased from £130 to £179. In general, however, the post-war increases of air transport fares at the end of 1949 only amounted to about 35 per cent. of pre-war rates, compared with wholesale commodity price advances of 125 per cent. and railway fare increases of 55 per cent. in the United Kingdom.

Although standard fares in areas affected by the value of sterling have recently shown a further slight upward movement, for which revaluation is mainly responsible, this movement has been partially offset by the increasing application of short period and other specially reduced return fares.

In discharging its paramount responsibility for securing agreed rates, which necessarily involves careful co-ordination of rate Resolutions on a world-wide basis, I.A.T.A. must be on its guard against the inherent danger of rigidity and lack of flexibility in its rate structure. Considerable progress has been made with the introduction of sub-standard fares such as "off season" fares, special fifteen-day return fares on the North Atlantic during January to March, creative fares to promote traffic during "off peak" hours, special event fares for international exhibitions, congresses and similar events, and so on. Nevertheless, there seems to be scope for greater elasticity in fixing rates to meet conditions peculiar to certain areas, or circumstances, in which there is a public demand which cannot be satisfied adequately within the existing rate structure. There are admitted difficulties in relaxing the security of uniformity in favour of the risks of abuse of flexibility, but the level of fares dictated by the standards of passenger accommodation and variable load factors of all-the-year-round operations on the North Atlantic are not necessarily appropriate to short period migration, or other mass movements which guarantee high load factors and, in certain areas, demand much lower standards of passenger accommodation. The lower levels of fares recently agreed for the Middle East area and certain Far East routes might well be found, as a result of close study on a regional basis, to be capable of wider application, with resultant benefits both to airlines and the public they serve.

### 3.4. Air mail conveyance rates

This survey would not be complete without mention of the important subject of air mail conveyance rates. As the history of the pre-war International Air Traffic Association and the more recent experience of the present International Air Transport Association will show, airlines from the beginning have experienced the greatest difficulty in securing recognition of the value of the service which air transport can render in the carriage of mails, especially on long distance services. National Postal Administrations in the discharge of their responsibilities naturally seek to offer their services to the public at the cheapest possible rate. There is the dual incentive of efficiency of the postal service and service to the nation in facilitating trade and other relationships. Transport charges obviously exert a preponderant influence on postage rates and it is in the interests of Postal Administrations to obtain the lowest possible rates for conveyance of mails. Nationally, through the monopolies they enjoy and, internationally, through the Universal Postal Union, Postal Administrations are in a powerful bargaining position.

Airline operators, on the other hand, recognise the importance of the acceleration they have to offer, compared with surface transport, in the conveyance of mails on international routes. The value of this acceleration obviously increases with

distance. The airline operator therefore claims a transport rate commensurate with the value to the public of the service he has to offer.

Widely different conclusions on a reasonable commercial rate for conveyance of mails can result from these differing approaches. Most Postal Administrations oppose the payment of rates for mails which contain any element of subsidy to other forms of traffic. Although they recognise that current passenger fares and freight rates are below airline profit levels and would not, therefore, be a reasonable basis for air mails, they consider that, in order to avoid any subsidy element, payment for mails should bear some relationship to costs of operation, plus a margin for profit. The airline operator, for his part, claims the right to a mail conveyance rate based, as are his passenger and freight rates, on the charge the user is able and willing to bear. He claims that the principle of differential rates is well established in industry, including other transport industries. In any industry where more than one commodity or service is produced by a single process, the general practice is to fix prices for each product by reference to the marketable value to the consumer in such a way as to ensure that the overall return at least covers total costs. The airline operator holds that the application of these well recognised commercial principles to air traffic would clearly justify much higher rates for mails, without importing any suggestion of subsidy to other forms of traffic. Mails, more than other classes of traffic, benefit from air transport; the revenue from mails is widely diffused in its incidence on the public and the letter writer, in return for a modest charge, secures in far greater measure than the individual passenger or consignor of freight, the benefits of air transport. So runs the argument of the airline operator for a rate which, even though it may yield a profit, contains no element of subsidy.

These differing viewpoints have been resolved, by compromise, in settling the rates which a Postal Administration should pay for mails conveyed by a foreign airline. These rates are settled between the Universal Postal Union and I.A.T.A. These two bodies have agreed that Postal Administrations using the services of a foreign operator should pay a rate of three gold francs a tonne-kilometre for short haul services, *e.g.* intra-European services, and six gold francs a tonne-kilometre for long haul services. It is true that these rates are regarded by the U.P.U. as maxima and by I.A.T.A. as minima, but they are applied in practice as the standard rates for carriage of mails by foreign operators. The agreement, however, does not extend to the rates to be paid by a Postal Administration to its national airlines. By long established practice each country reserves the right to determine the contractual relationship between its Postal Administration and its airlines. With few exceptions, Postal Administrations pay rates below the "international" rate to the airlines of their own country.

Existing United States national policy, however, is far-sighted and appears to recognise that the user of air mail, as the greatest beneficiary from air transport, can contribute to its development in order to secure the long-term objective of cheaper rates without bearing an undue share in the present. Under the Civil Aeronautics Act 1938, the Post Office Department is established as the fiscal instrument for the encouragement and development of a satisfactory air transport system. It directs the Civil Aeronautics Board to consider "the need for each . . . . air carrier for compensation . . . . sufficient . . . . to enable such carrier under honest economical and efficient management to maintain and continue the development of air transportation to the extent and of the character and quality required for the commerce of the United States, the Postal Service and the national defence." Thus, given honest economical and efficient operations, the United States airline operators' short-fall of revenue from passengers and freight is provided from mail revenues at the disposal of the Postal Department. Admittedly there is some element of subsidy in these balancing payments from mail revenues but, unless these air transport "need" payments by the Postal Department exceed mail revenues, the incidence of that subsidy falls on the vast public which uses the air mail system, rather than on the general public which contributes to the national taxation system. (A change of United States policy, which will divorce subsidy from air mail payments and revenues, has recently been approved by the President for legislative action.)

Whatever may be the merits of a subsidy to air transport contributed by air mail revenues, as opposed to a straight Exchequer subsidy unrelated to any particular source of

revenue, there is certainly an arguable case, in the interests of air transport development, for remunerating airline operators at rates not less than those internationally agreed between the U.P.U. and I.A.T.A., without importing any element of subsidy or imposing unreasonable charges on the user.

On the merits of the international rates of three gold francs and six gold francs a tonne-kilometre, the wide differential is scarcely justified by the relatively small differences in costs of short haul and long haul operations. Bearing in mind that national policies are inclined to favour the national operator, mail traffic tends to be one way and to be unmatched by return loads. The airline, therefore, has to face the unproductive costs of unfilled capacity in one direction. The lower rate of three gold francs can only be justified by the "all up" system, under which all first class mails are carried by air. "All up" systems which leave the user without surface transport option must necessarily avoid high postage rates, and airline operators must depend for their revenues on narrower profit margins on heavier loads. As experience of the Empire Air Mail Scheme has taught the Commonwealth, the "all up" principle is not satisfactory to the long distance operator, who does not possess the aircraft flexibility of the high frequency short haul operator in dealing with mail traffic peaks which, under the Empire Air Mail Scheme, occurred particularly at week-ends and at certain seasons. Thus, while there are formidable practical objections to substituting "all up" for surcharged mails on long distance routes, the "all up" system has been found workable on intra-European routes. But the yields to the short haul operator at existing rates are small in relation to the return capacity he employs, and do not seem to recognise sufficiently the useful part air mails can legitimately be expected to play under any forward-looking policy of air transport development. Postage surcharges on long distance air mails, which secure the maximum benefits of air transport acceleration, without depriving the user of his option of cheaper and slower surface transport conveyance, might be so fixed as to produce the revenues necessary to improve somewhat the lower international rates of three gold francs for the short haul operator.

The twin-rate mail structure as such has the merit of simplicity and does not seem open to serious objection, but the differential might be narrowed by increase of the lower rate.

## 4. SUBSIDIES

Sir Henry Self, in his lecture before the Society in 1946*, explained the various forms of subsidies ranging from direct payments to airlines (through the media of State subsidies and air mail payments) to indirect State Assistance in the forms of (*a*) aerodrome and navigation facilities at less than cost, (*b*) expenditure on aircraft research and development not fully recouped in aircraft prices, (*c*) taxation concessions and so on. He also demonstrated the economic and social justification for State assistance during the evolutionary years of the new industry and drew a clear distinction between necessary subsidies for the development of a new industry and the misuse of subsidisation designed to secure competitive advantages or to mask inefficiency.

The scale of subsidisation should be the acid test of progress of international air transport. But it is, in fact, a baffling amalgam, which defies analysis, of the effects of such elements as national policies governing the exchange of commercial rights, technical advancement, operational cost trends, tariff levels and lack of balance in the relationship between capacity and traffic. For the purpose of this survey, however, I would pose two questions for examination:—

(1) Is progress being made with reducing the scales of State assistance to air transport?

(2) In what order and with what prospects should endeavours be made progressively to reduce, and ultimately to eliminate, subsidies?

In dealing with these questions I propose to draw on United Kingdom experience, which in general tendency, although not necessarily in incidence, is probably sufficiently representative for the purpose.

Under (1) we find that while direct subsidy payments to operators in these post-war years have greatly increased, compared with pre-war years, in total sums paid by the taxpayer, they have declined progressively in the past 20 years in terms of output. The figures are as follows:—

*Second British Commonwealth and Empire Lecture, The Status of Civil Aviation in 1946. Sir Henry Self. JOURNAL R.Ae.S., October 1946, pp. 719-784.

| | Subsidy | Total L.T.M.s | Subsidy per L.T.M. |
|---|---|---|---|
| 1929/30 | | | |
| Imperial Airways | £342,000 | 976,000 | 84d. |
| 1938/39 | | | |
| Imperial Airways | £1,234,000 | 11,350,000 | 26d. |
| 1949/50 | | | |
| B.O.A.C. (Incl. B.S.A.A.) and B.E.A. | £7,885,000 | 93,247,000 | 20d. |

(*Note: The Load-Ton-Mile* (*L.T.M.*) *is the only unit of output in common use throughout the period*).

The fact that the rate of subsidy has declined from 26d. a load-ton-mile in 1938 to 20d. a load-ton-mile in 1949 is perhaps a useful corrective of certain current misconceptions, especially when the latter figure is adjusted for the reduced value of sterling. Added to this we must bear in mind that increases in air transport fare levels over pre-war rates are below the average increases of commodity prices and surface transport rates. Hence, it is not unreasonable to assume that the future holds encouraging prospects of declining subsidies in the form of direct payments to airlines. Coming aircraft types show promise of substantial improvement in the output/cost ratio. By 1955 a direct operating cost (excluding overheads) of $1\frac{3}{4}$d.a seat-mile should be possible on North Atlantic services. Given economic levels of rates of carriage, the abatement of present restrictive policies and improving traffics as the counterpart of these diminishing costs, there is no reason why direct subsidisation should not disappear within the next few years.

But when we turn to indirect assistance we find that this favourable trend has .been reversed. The most significant form of indirect assistance is the provision of airport facilities at substantially less than cost. The provision of international airports today is a responsibility of Governments, but the development of expensive runways and hangarage for heavy aircraft types, the adoption of modern systems of air traffic control and air navigational aids to improve regularity of operation under conditions of adverse weather and growing traffic density, have increased enormously the capital and recurrent costs of providing the ground organisation for international air transport. It would not have been possible to have imposed on airlines increased scales of landing fees and other charges for these facilities, commensurate with the greatly increased costs, without crippling the infant industry we seek to foster. In the result the burdens falling on taxpayers in the post-war years in the provision of aerodrome and ground facilities generally are heavy.

Before the war Croydon was still our first international airport, but it was a grass aerodrome, and modern concrete runways of great length and bearing strength and large-scale hangarage had not become necessary. The estimated capital expenditure on Croydon Airport during the fourteen years 1926 to 1939 was about £400,000. By contrast the capital expenditure on London Airport during the four years 1946/7 to 1949/50 is of the order of £10,000,000 and likely to increase to £26,000,000 before the airport is completed. Annual expenditure on operation and maintenance of aerodromes has increased in like measure, but a much smaller proportion of this heavier expenditure is recovered in revenues from the landing fees and other aerodrome charges. In 1938/39 revenue amounted to 90 per cent. of annual operating expenditure at Croydon, *i.e.* excluding depreciation and interest on capital. The corresponding figure for the London Airport in 1948/49 was 69 per cent., but this figure is reduced to 22 per cent if depreciation and interest on capital are included.

The incidence of the burden of State assistance, therefore, has been transferred over the past 20 years from direct subsidies to operators to indirect assistance, chiefly through the ground organisation. While it may be right that air transport should not be expected, any more than other forms of transport, to become entirely self-supporting, we must look towards not only the extinguishment of direct subsidies to operators, but an increasing reduction in forms of indirect assistance as the air transport industry develops.

This leads naturally to the second question, namely, in what order and with what prospects should endeavours be made to reduce, and ultimately to eliminate, subsidisation.

As has already been suggested, a continuance of present trends indicates the possibility of progressive reduction of direct subsidy payments to airlines. Whether it is the right course to aim at the entire elimination of direct subsidies, before any attempt is made to secure increased contributions towards aerodrome and ground organisation facilities, is a question on which opinions will differ. The direct subsidy has well-

recognised drawbacks. It may act as a brake on initiative, enterprise and resourcefulness; it may cloak inefficiency; it may, unless watched by Governments, lead to reductions in fare levels at a faster pace than economic considerations would justify, and it may provide a convenient medium of concealment of competitive subterfuges designed to gain unfair advantages. So long as international air transport requires direct subsidy support there is no reliable yard stick of national rates of subsidy necessary to support an efficient industry in its present stage of evolution. Consequently the measure of the subsidies attributable to other causes, including considerations of national policies, remains obscured. It might have a salutary effect on Governments if they had a more exact measure of the cost to them of any national policies which may influence their participation in international air transport. These are arguments which seem to point to concentration first on the elimination of forms of subsidy involving direct payments to airlines.

But there are counter-arguments to such unqualified priority of treatment to be considered. Indirect assistance in some of its forms may be equally open to some of the foregoing objections. The main form of indirect assistance—through the aerodrome and ground organisation—has the merit of being non-discriminatory in its incidence between international airlines and does not provide a medium for competitive abuses, if the conditions of the Chicago Convention are scrupulously observed. Nevertheless a form of assistance which is only reflected in the national budget, and not in the profit and loss account of the airline, is apt to create an illusory appearance of successful progress towards self-sufficiency in the industry. In such circumstances it is not unnatural that airlines, through I.A.T.A., will tend to adopt rates of carriage which would fail to take adequate account of the contribution the air transport user can legitimately be expected to bear, as operators' costs decline, in meeting increased aerodrome charges in relief of present burdens. In theory, Governments in the exercise of their rights of approval of I.A.T.A. recommendations can exercise the necessary measure of control over rates of carriage to take account of aerodrome charges. In practice, Governments act individually, and not collectively, on the Rate Resolutions of I.A.T.A. and until policies of Governments have been co-ordinated in dealing with this important form of indirect assistance, effective Government action to deal with the provision to be made for aerodrome charges, as part of the rate-fixing process, is not possible.

The International Civil Aviation Organisation, as the instrument of Governments, has embarked upon a study of these difficult problems and will no doubt propound solutions to its members. Meanwhile individual Governments have the task of deciding their own courses of action. Whatever may be the apparent advantages of first eliminating subsidies in the form of direct payments to airlines, it seems clear that indirect assistance, where it is of considerable magnitude, creates problems requiring concurrent solution.

A useful guiding principle, in deciding the timing and amount of increases of aerodrome charges, is the measure of contribution the traffic will bear without arresting the legitimate expansion of the industry. Current rates of landing fees amount, typically, to three per cent. of the revenues of a long distance airline. In my personal opinion the doubling of this relatively small percentage would make a material contribution to aerodrome revenues, and if the opportunity were taken to synchronise increases of landing fees with proposed reductions of fares and freight rates, so that the former represented only a modest percentage of the latter, neither the individual user nor the progress of the industry need be adversely affected.

It has now become evident that international air transport will have an increasingly important part to play in world communications systems. One may perhaps regard subsidisation as the forcing house of latent self-sufficiency in air transport, but in an industry in which the ability to expand by its own efforts is becoming increasingly apparent, the acceleration of its expansion with State assistance must be related to the measure of support it is reasonable to call upon the taxpayer to provide.

## 5. CONCLUSIONS

In drawing this survey to a close, I should like to repeat that its main purpose is to pass in review the history of the exchanges of commercial rights in international air transport, with particular emphasis on United Kingdom policies and the factors which have influenced those policies. If I appear, therefore, to have laboured those

passages dealing with multilateralism and bilateralism and to have devoted less attention to the important allied subjects of rates of carriage and subsidies, it is because I believe that policies governing the exchange of routes and traffic rights will exercise a more profound influence than any other factor on the fortunes and future of international air transport. The scientist, technician and airline operator have provided the necessary assurances that air transport can justify itself economically, given the necessary freedom to expand. The task that lies ahead is the removal of artificial political and economic barriers which impede the process of self-realisation. Diagnosis is a pre-requisite of treatment, and if this analysis of the obstacles to air transport development can contribute to their solution, it will have served some purpose. Its main features may be distilled in the form of the following summary of conclusions.

1. The nature of rights to carry traffic, at present secured through inter-Governmental bilateral Agreements, exercises a profound influence on international air transport. The governing doctrine of the Five Freedoms of the air and associated regulation of capacity which may be offered on international routes have become firmly established in all national policies. Although successive attempts to achieve a form of multilateral code, based on sound principles of orderly development, have failed, the expansion which awaits international air transport will be retarded until enlightened multilateral co-operation can be achieved. This is unlikely in the near future, owing to widely divergent national views.

2. Considerations of national prestige and defence, already pronounced features of the inter-war years, continue to dominate international relationships in air transport and have produced the firmly established principle of reciprocity, which normally expresses itself in the form of competitive parallel operations between the territories of the parties to bilateral Agreements. Among the consequences are:—

(*a*) The defeat of multilateralism and survival of bilateralism as the instrument for exchange of routes and traffic rights.

(*b*) Wasteful duplication of effort on many routes, irrespective of traffic justification.

(*c*) Increasing growth of policies of self-protection and consequent restrictions on the grant of routes and traffic rights.

(*d*) Self-protection and restrictions have placed a premium on efficiency, have retarded expansion and led to subsidisation beyond the needs of efficient development of a new industry.

3. The inherent difficulties of bilateralism, accompanied by reciprocity and restrictive policies, have been aggravated by the failure of post-war traffic to live up to expectations of expansion. Among the causes are unsettled world conditions, currency restrictions and rising costs.

4. The Bermuda type Agreement is the best yet evolved to meet conditions of competing reciprocal operation. It is flexible, holds the balance fairly between competing interests, promotes expansion and rewards efficiency within controlled limits.

5. During the difficult years immediately ahead the growth of air transport might be assisted by the extension, where feasible and beneficial, of forms of co-operation already in operation in the Commonwealth, namely, joint ownership and operation, parallel partnership form of "pooling" operations and rationalisation by division of routes between operators, according to resources and responsibilities. Constructive measures of co-operation provide a saner approach than self-protection and restrictions which stultify development.

6. The policy of the agreed rates of carriage is one of the major post-war advances in securing orderly development of international air transport. I.A.T.A. has already a remarkable record of achievement to its credit but greater flexibility in its rate structure seems possible in the interests of traffic promotion. Governments can also improve the effectiveness of the work of I.A.T.A. by accelerating their decisions on Rate Resolutions.

7. Further considerations should be given to the question whether air mail rates cannot legitimately be expected to make a greater contribution to air transport development, without importing any suggestion of subsidy to other forms of traffic, or charging the air mail user a postage rate not justified by the benefits of the service rendered.

8. There is evidence of a declining trend over the past 20 years in the rate of subsidies paid to airlines in terms of output. This

## APPENDIX I
## THE FIVE FREEDOMS OF THE AIR

FREEDOM I

RIGHT OF TRANSIT WITHOUT LANDING

FREEDOM II

RIGHT OF NON-TRAFFIC STOP FOR REFUELLING, ETC., BUT NOT SETTING DOWN OR PICKING UP LOAD

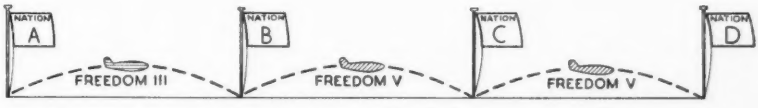
FREEDOM III

RIGHT TO SET DOWN TRAFFIC FROM NATION "A" AT NATION "B"

FREEDOM IV

RIGHT TO PICK UP TRAFFIC FROM NATION "B" FOR NATION "A"

FREEDOM V




RIGHT TO CARRY TRAFFIC BETWEEN FOREIGN TERRITORIES, E.G. NATION "B" & NATION "C"

FREEDOM VI (CABOTAGE)

RIGHT TO CARRY TRAFFIC WITHIN TERRITORY OF A FOREIGN NATION

Chart related to a hypothetical aeroplane belonging to Nation "A."

trend should continue, given economic rates of carriage, the abatement of policies of self-protection and restriction and improving traffics, but the need for greater contributions to the cost of the ground organisation should be recognised as reductions in rates of carriage become possible.

These conclusions are, in brief, my personal diagnosis of the present state of the economic development of international air transport. The problems we face in air transport today reflect a world of rapid social changes, technical advances and political upheavals and conflicts. Air transport is symbolic of the era: it makes its own contribution to the shifting scene of social and economic changes and, in its own development, presents many of the transitional problems of the changing order. The conservative mind instinctively recoils from change. The zealot grasps it with ebullient enthusiasm, often blind to its obstacles and problems. In air transport we should cultivate a resolute and sober optimism which blends imaginative enthusiasm with realism born of experience. We should face our problems in a spirit of challenge to the future and in the conviction that, with faith and determination, we can foster and consolidate a great international enterprise whose boundaries are the limitless horizons of the air.

## APPENDIX II
## DRAFT CAPACITY CLAUSE

*Prepared at the Multilateral Commission of the International Air Transport Association, Geneva, 1947*

1. The capacity provided by the designated airlines of a party to a route agreement together with the capacity provided by the designated airlines of the other party shall be maintained in reasonable relationship to the requirements of the public for transportation on the agreed routes.

2. In the application of the principle stated in Paragraph 1 above.

(*a*) The air services provided by a designated airline under a route agreement shall have as their primary objective the provision at a reasonable load factor of capacity adequate to the current and reasonably anticipated requirements of that airline for the carriage of passengers, mail and cargo originating in or destined for the territory of the party designating the airline.

(*b*) The capacity provided under Sub-paragraph (*a*) may be augmented by capacity adequate for the carriage of passengers, mail and cargo both originating at and destined for points on the agreed routes in the territories of States other than that designating the airline. Such additional capacity shall be related to the traffic requirements of the areas through which the airline operates, after taking account of the special position of other air services established by airlines of the States referred to above, for the purpose of carrying traffic originating in or destined for their territories.

(*c*) This article shall not be interpreted to require changes in capacity more frequently, nor at a larger number of points along a route, than is consistent with sound operating practices of international air services.

3. Nothing in this article shall prevent unfilled capacity in any aircraft, operated in accordance with this article, from being used for the carriage of any international traffic in passengers, mail and cargo offered.

4. In the case of through tickets allowing of breaks in the journey, the destination for the purpose of this article is the final destination to which the passenger is entitled to travel by his ticket and subject to the conditions of its issue. The parties to a route agreement shall, if they so desire, make provision in the route agreement for the determination of the destination of cargo for the purpose of this article.

## VOTE OF THANKS

Following the Lecture a vote of thanks was proposed by Marshal of the Royal Air Force Lord Douglas of Kirtleside, Honorary Companion of the Society, Chairman of British European Airways and was seconded by Sir Frederick Handley Page, C.B.E., Honorary Fellow of the Society, Past President.

**Lord Douglas of Kirtleside:** It was a pity that there could be no discussion of the Lecture, because a discussion on so stimulating a lecture would have been most interesting. There was much in it that he would have liked to have discussed, and no doubt many more would have liked to have had their say.

It would be agreed, however, that the meeting had listened to a most interesting address, setting out many international problems in a very rational form, so that all could grasp them and turn them over in their minds. It was a very pleasant duty to move a warm vote of thanks to Sir George Cribbett.

**Sir Frederick Handley Page, C.B.E.:** He had been greatly impressed by Sir George Cribbett's survey of aviation agreements and developments. At one time his thought had been that the principal requirement for an airline was a good aeroplane, but listening to the Lecture he had concluded that it was necessary to be an excellent lawyer and a most extraordinary diplomat in order to deal successfully with all the artificial barriers that had grown up, arising from the fact that mankind, without the easy means of transport which the air afforded, had segregated himself into little entities in which nationalism and a lot of other "isms" had developed. If he were so rash as to start an airline today he would choose the Foreign Secretary as one of the Directors, and the Attorney General as another.

The Royal Aeronautical Society had been fortunate in its choice of British Commonwealth and Empire Lecturers, who had discussed aircraft design, development and operation, and it had again chosen well in Sir George Cribbett. He had never known before anybody who had been a pilot and had also engaged in the accurate investigation of accounts and a precise check of national expenditure. This combination was rare, although he had often thought, when dealing with some pilots, that a greater appreciation of the financial implications would be an exceedingly good thing!

Having listened to what the President had said about Sir George's career, he had felt that the Minister of Civil Aviation was exceedingly fortunate in having Sir George as one of the principal pillars of the Ministry, and that the Royal Aeronautical Society was also fortunate in having persuaded him to deliver so interesting a lecture. It was with the greatest pleasure that he seconded the vote of thanks.

Following the Lecture a dinner was given by the Council of the Society at 4 Hamilton Place, at which the following were present:—

Air Marshal J. N. Boothman, C.B.E., D.F.C., A.F.C., Controller of Supplies (Air), Ministry of Supply; E. C. Bowyer, Esq., Director, Society of British Aircraft Constructors; Sir John S. Buchanan, C.B.E., F.R.Ae.S., Past President; Major G. P. Bulman, C.B.E., B.Sc., F.R.Ae.S., President, Royal Aeronautical Society.

V. Christensen, Esq., London Manager, Scandinavian Air Lines; Group Captain C. Clarkson, A.F.C., A.F.R.Ae.S., M.I.Ae.S., Civil Air Attaché, Washington; Air Chief Marshal Sir W. Alec Coryton, K.C.B., K.B.E., M.V.O., D.F.C., Chief Executive, Guided Weapons, Ministry of Supply; Dr. H. Roxbee Cox, D.I.C., F.R.Ae.S., Past President; Lieut. General Sir Kenneth N. Crawford, K.C.B., M.C., Controller of Supplies (Munitions), Ministry of Supply; Sir George Cribbett, K.B.E., C.M.G., Sixth British Commonwealth and Empire Lecturer.

Dr. G. P. Douglas, O.B.E., M.C., F.R.Ae.S., Member of Council; G. H. Dowty, Esq., F.R.Ae.S., Chairman and Managing Director, Dowty Equipment Ltd.

G. R. Edwards, Esq., M.B.E., B.Sc., F.R.Ae.S., Vice-President; Air Marshal Sir Aubrey B. Ellwood, K.C.B., D.S.C., Air Officer Commanding-in-Chief, Transport Command, R.A.F.

Sir A. H. Roy Fedden, M.B.E., D.Sc., F.R.Ae.S., Past President; W. Hudson Fysh, Esq., D.F.C., A.F.R.Ae.S., Managing Director, Quantas Empire Airways.

Air Marshal Sir Guy Garrod, G.B.E., K.C.B., M.C., D.F.C., M.A., F.R.Ae.S., President, Air League of the British Empire; W. T. Gill, Esq., President, Society of British Aircraft Constructors; Sir Arthur Gouge, B.Sc., F.R.Ae.S., Past President.

Major F. B. Halford, C.B.E., F.R.Ae.S., Vice-President; Professor A. A. Hall, M.A., F.R.Ae.S., Member of Council; S. Scott Hall, Esq., M.Sc., D.I.C., F.R.Ae.S., Member of Council; N. J. Hancock, Esq., A.F.R.Ae.S., Member of Council; Wing Commander N. M. Heath, O.B.E., Representing the Australian Resident Minister.

The Lord Douglas of Kirtleside, G.C.B., M.C., D.F.C., Chairman, British European Airways Corporation.

Captain A. G. Lamplugh, C.B.E., F.R.G.S., F.R.Ae.S., Underwriter and Principal Surveyor, British Aviation Insurance Co. Ltd.

Major J. R. McCrindle, O.B.E., M.C., Overseas Adviser on International Affairs, British Overseas Airways Corporation; Sir John Makins, Chairman, British Aviation Insurance Co. Ltd.; P. G. Masefield, Esq., M.A., F.R.Ae.S., Member of Council; His Excellency V. K. Krishna Menon, High Commissioner for India; F. C. Musgrave, Esq., C.B., Under-Secretary (Air), Ministry of Supply.

Sir Arnold E. Overton, K.C.B., K.C.M.G., M.C., Permanent Secretary, Ministry of Civil Aviation.

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# A COMPARATIVE STUDY OF THE NOISE FROM TURBO-JET AND RECIPROCATING AIRCRAFT ENGINES IN FLIGHT

by

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SUMMARY

Sources of noise in aircraft are discussed briefly with particular reference to the introduction of the turbo-jet engine.

An account is given of a particular investigation made in a Lancastrian aircraft fitted with both turbo-jet and reciprocating engines. The equipment by which the noise spectrum was analysed over an extended frequency band is described.

The results are examined and the effects of the two types of engine on the noise spectrum are compared, under different representative conditions, in the forward and rear sections of the fuselage.

## 1. INTRODUCTION

Noise is generally defined as sound which is undesired by the recipient. The degree of discomfort and annoyance depends on the sound pressure level, the frequency spectrum of the sound components, the duration of the noise and the individual susceptibility to discomfort of the listener.

Noise has always been considered as a nuisance in industry and a new source of intense noise has come into being with the advent of aviation. The noise generated by an aircraft in flight causes annoyance to people on the ground and interferes with the correct functioning of the Radio Telephone and Inter-communications systems inside the aircraft. In long flights, intense and persistent noise may be a hazard to the hearing acuity of the members of the air crew without ear protection. The problems associated with noise become greater every day with the increasing engine power and consequent increasing air speed, of modern aircraft.

Paper received May 1950.

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Various workers have investigated the problem of aircraft noise within the frequency range which constitutes the audible spectrum. Some have studied noise from the clinical aspect and others from the point of view of noise as a source of interference in communications. Besides the published work on noise from aircraft in flight, many reports have been issued by various Committees, either governmental or industrial. The experimental evidence so far gathered, can be summarised in the statement that most of the energy in the radiated noise from piston-engined aircraft is confined to the low frequency end of the audible spectrum, but for turbo-jet-engined aircraft it may extend to higher frequencies, probably stretching well beyond the audible range into the ultra-sonic region.

In this paper, an experiment is described in which the author and his colleagues of the Royal Air Force Acoustics Laboratory have carried out, under similar conditions of flight, analyses of noise produced by both turbo-jet engines and reciprocating engines fitted to a Lancastrian. Some information about the nature of aerodynamic noise in flight at moderate air speeds has also been obtained. The frequency range covered is from 50 cycles a second to 60,000 cycles a second, the present upper limit of the analysing apparatus.

## 2. NATURE OF NOISE OF AN AIRCRAFT IN FLIGHT

It is generally agreed that the noise generated by an aircraft in flight consists mainly of the following components:—

(*a*) Engine noise
(*b*) Propeller noise
(*c*) Aerodynamic noise
(*d*) Noise originating from the vibrations of the airframe and engines

(*e*) Residual noise due to the operation of the various mechanical devices inside the aircraft, of an intermittent and persistent nature. Of these the first three components are of primary importance.

(*a*) *Engine noise*

Noise is generated by the moving parts of the aero-engine and by the exhaust system. The noise from piston engines has been dealt with by other workers, such as Beranek (1944)[2], Fleming (1946)[5], Chavasse and Lehmann (1947)[3], to mention but a few, and will be discussed here only in comparison with turbo-jet noise. The principal source of noise in a piston engine seems to be from the reduction gear box coupling the engine to the propeller, the explosions inside the cylinders and the exhaust. The air intake also contributes to the engine noise. Of these, the contribution from the exhaust is the strongest component. The noise from multiple exhaust stubs discharging into the open air can be reduced by various modifications of the stub system. From some measurements made on a York aircraft[1] it was found that a maximum reduction in exhaust noise can be obtained by letting all the stubs discharge into a common manifold. The reduction in noise under the last mentioned condition appears mainly in the low and medium sonic frequencies. It seems probable, however, that the noise from piston-engines contributes very little to the overall noise above 10,000 c.p.s.

It has been shown that the character of the noise generated by a turbo-jet engine is different from that produced by a reciprocating engine[4]. The air intake, combustion and exhaust jet, contribute a continuous spectrum of random frequency noise while periodic components of very high fundamental frequency, due to the revolution of the impeller and turbine, include harmonics extending into the ultra-sonic range. Of these sources the most important is the jet itself, the noise being due to turbulence set up at the boundary layer between the hot exhaust gases and the cold air into which they are discharged at high relative velocity.

(*b*) *Propeller noise*

In piston-engined aircraft and in propeller-turbine aircraft, additional noise is created by the propellers. The noise level due to the propeller inside a propeller-driven aircraft is proportional to the speed of the rotating tips of the propellers, power per blade and the clearance between the tips of the propellers and the fuselage[9]. It has been found by experience that tip-speed in excess of 700 feet a second at the cruising speed of a transport aircraft, causes excessive noise; the cruising tip-speed therefore is usually limited to the foregoing figures[7]. The tip-speed at take-off (for a transport aircraft) is between 900 and 1,000 feet a second. In propeller-turbine aircraft the economical cruising speed is said to be 90 to 96 per cent. of maximum engine speed. The designer therefore is left with the alternative of increasing the cruising tip-speed, with consequent increase in noise, or reducing the take-off thrust, by lessening the tip-speed at take-off to conform with the requirements of comfort.

If the power loading for a blade is reduced, as for example when a three-bladed propeller is replaced by a four-bladed one in a particular aircraft, the noise may be reduced by an amount varying between 6 and 10 decibels in the plane of the propellers and 3 to 6 decibels in the rear cabin[1].

An aircraft designer has little latitude in fixing the clearance between the airscrew and the fuselage in his attempt at reducing noise. This clearance is generally of the order of 12 inches.

Because of the absence of propellers, it may be expected that the noise inside a turbo-jet aircraft will be low, compared with that inside an equivalent piston-engined aircraft for the same air speed.

(*c*) *Aerodynamic noise*

This noise originates from the passage of any part of the aircraft through the air. Any protuberances in the aircraft structure, such as the cockpit hood, and the astrodome, as well as any irregularities in the streamlining of the fuselage, cause turbulence. The noise thus generated has components of all frequencies, the sound pressure level of which in general decreases with increasing frequency. At the much higher air speeds of which turbo-jet aircraft, particularly the latest fighters and bombers, are capable the aerodynamic noise due to turbulence around wing tips and other protuberances increases rapidly and may well contribute almost 95 per cent. of the total noise energy[8].

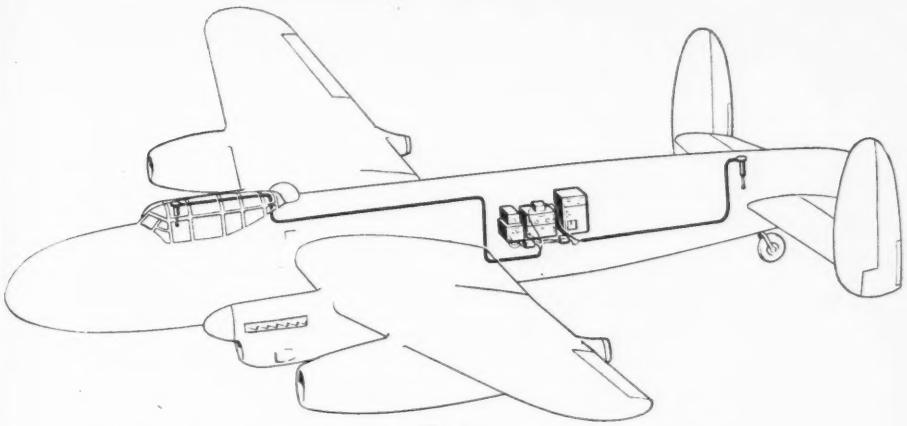

Fig. 1.
Location of microphones and measuring equipment.

## 3. AN EXPERIMENT IN FLIGHT

A special four-engined Avro Lancastrian was made available for tests through the courtesy and co-operation of The de Havilland Engine Company Ltd. This aircraft was originally fitted with four Rolls-Royce Merlin engines of 1,285 b.h.p. each driving a three-bladed propeller. The de Havilland Engine Company had removed the two outboard Merlin reciprocating engines and fitted two Ghost turbo-jet engines. The maximum speed of rotation of the Ghost engine was 10,250 r.p.m. and each of these could produce a maximum static thrust of 5,000 lb.

This particular aircraft lent itself ideally for the comparative study of noise for the two types of engines in flight.

### 3.1. The analysing apparatus

A well-known narrow band analysing apparatus was used for the frequency range 50 cycles a second to 7,500 cycles a second, namely the General Radio Noise Meter type 759 B and its associated Analyser type 760. The microphone, which is an integral part of the equipment, is of the piezo-electric type and has been calibrated by the makers in conjunction with the noise meter. The analyser itself is a constant percentage bandwidth instrument with a selectivity such that at one per cent. deviation from the mid-frequency of the band under measurement, the response is reduced by 3 decibels and at a hundred per cent. deviation, by 35 decibels. The lowest sound pressure that can be measured is 24 decibels and the highest 140 decibels, relative to a pressure of 0.0002 dynes/cm.$^2$ The low frequency analysing equipment is shown in Fig. 11.

As no high frequency noise analyser was available in the United Kingdom at the time, two types of high frequency microphone were developed for the purpose to cover the frequency band 7,000 cycles a second to 60,000 cycles a second. Both are miniature microphones, one of the piezo-electric type and the other of the condenser type. The piezo-electric type employs a multiple slab Ammonium Dihydrogen Phosphate crystal 3/16 inch square and 1·/4 inch long, varnished and copper-plated.

The condenser microphones have Platinum Iridium diaphragms, with an effective diameter of 1/4 inch. Their overall diameters are one inch. Fig. 10 is an exploded view of the R.A.F. High Frequency Condenser microphone.

Both types of microphone were used in conjunction with a British General Post Office constant band-width heterodyne analyser comprising a Selective Frequency Changing Equipment, type Ex 25090 and a Wide-band Measuring Set, type Ex 25120. The frequency range of the G.P.O. analyser is from 1,000 cycles a second to 800,000 cycles a second and it operates with an intermediate frequency of 800,000 cycles a second. The selectivity is such that the response is three decibels below maximum at 150 cycles a second deviation from the intermediate frequency, and 35 decibels at 1,400 cycles a second deviation.

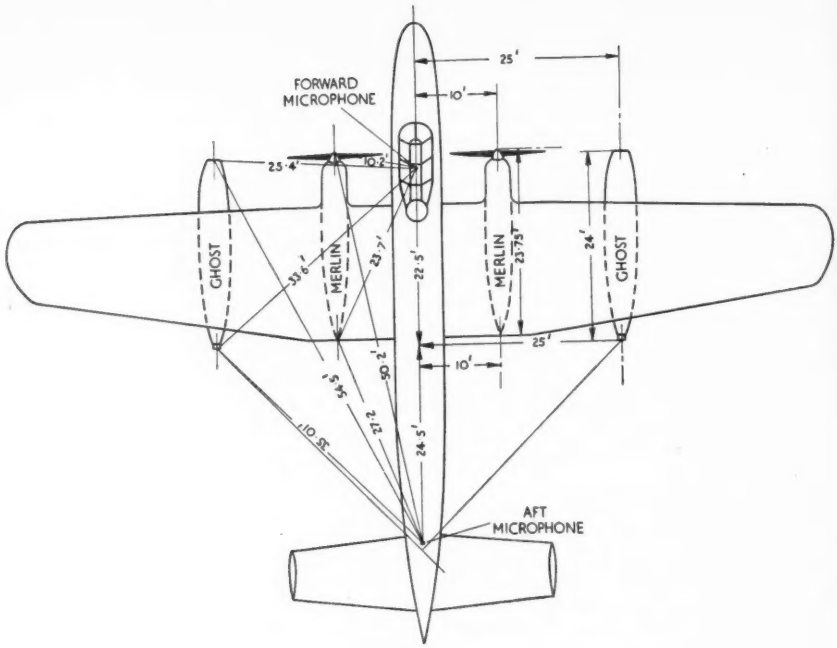


Fig. 2.
Plan view of Ghost Lancastrian showing position of microphones for sonic and ultrasonic measurements. Wing span: 102 ft. Length: 77 ft. 6 in.

Both the crystal and condenser microphones were calibrated in relation to an American high frequency hydrophone made by the Brush Development Company. The Brush instrument has been calibrated in the air by the makers for the frequency range of 1,000 cycles a second to 60,000 cycles a second, using the "Reciprocity" method of calibration. The Brush instrument was used first to calibrate a set of Hartmann Generators, each being 3,000 cycles a second frequency apart from its adjacent ones, to cover the whole of the high frequency range from 7,000 cycles a second to 60,000 cycles a second. The R.A.F. microphones were then calibrated against these sound projectors.

The same combination of an R.A.F. microphone and G.P.O. analyser was used for the purpose of noise analysis in flight in the high frequency range. The lowest sound pressure that could be measured by this combination was 55 decibels relative to a pressure of 0.0002 dynes/cm.$^2$ and the highest limit was 160 decibels. The high frequency analysing apparatus is shown in Fig. 12.

### 3.2 Measurements

The measurements were made at two different heights, namely at 5,000 feet and at 20,000 feet. Microphones were fitted in the pilot's cabin and in the luggage compartment at the tail of the aircraft.

In order to assess the sound pressure levels under different conditions, the aircraft was flown at a variety of air speeds and engine conditions. The sequence observed was, first the two Merlin engines, followed by the two Ghost engines and then all four engines running together. From these preliminary trials it was observed that on the two Merlin engines alone, the aircraft could fly at maximum air speeds of 190 m.p.h. at 5,000 feet and 142 m.p.h. at 20,000 feet.

The aircraft was then flown at 5,000 feet at 190 m.p.h. using Merlin engines only and the noise was analysed by two operators, one using the low frequency instrument and the

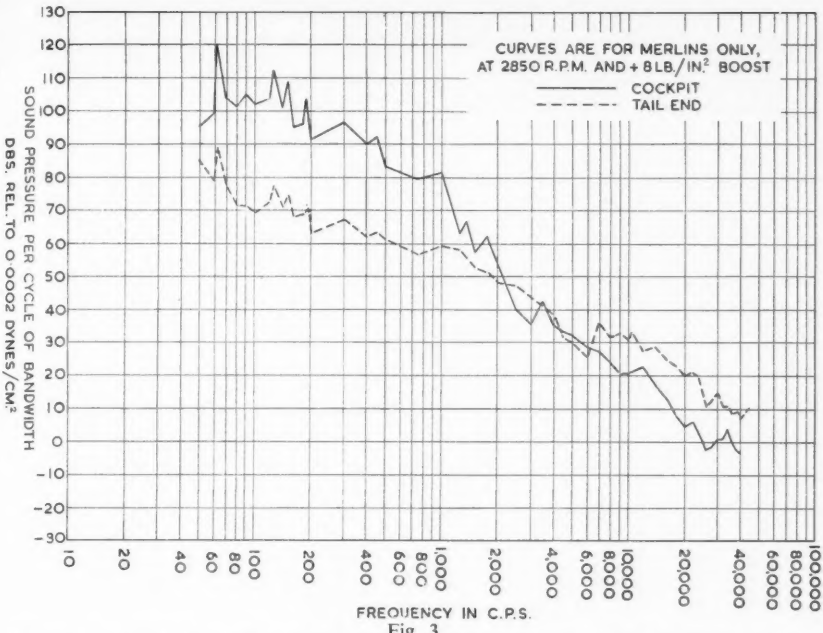


Fig. 3.
Narrow band analysis of noise spectrum (50-60,000 c.p.s.) from Ghost Lancastrian in flight. Altitude 5,000 ft. I.A.S. 190 m.p.h.

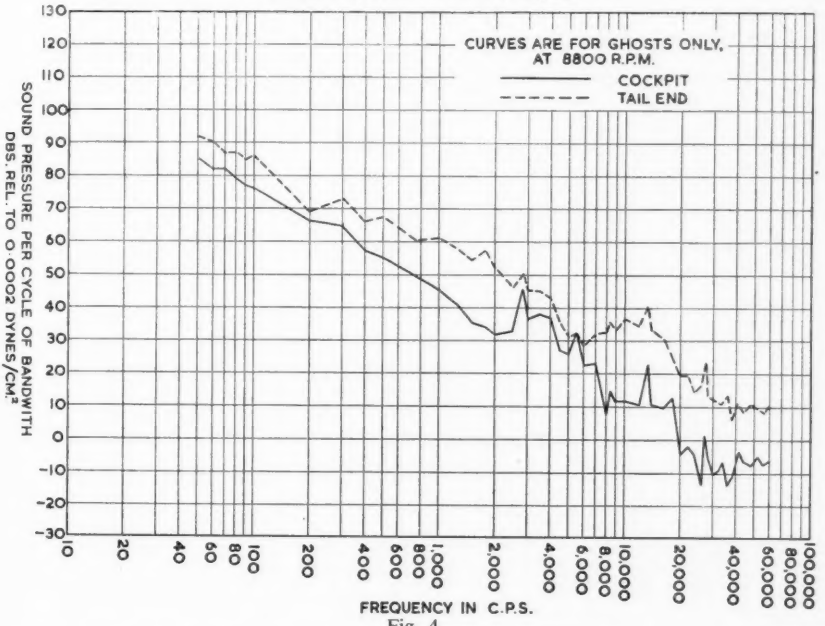


Fig. 4.
Narrow band analysis of noise spectrum (50-60 000 c.p s.) from Ghost Lancastrian in flight. Altitude 5,000 ft. I.A.S. 190 m.p.h.

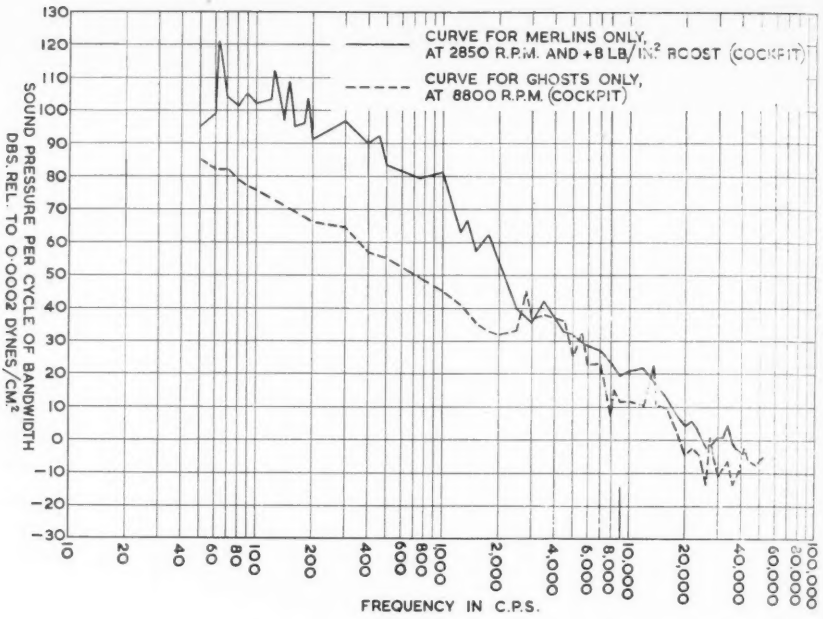
CURVE FOR MERLINS ONLY, AT 2850 R.P.M. AND +8 LB/IN.² BOOST (COCKPIT)
CURVE FOR GHOSTS ONLY, AT 8800 R.P.M. (COCKPIT)
SOUND PRESSURE PER CYCLE OF BANDWIDTH DBS. REL. TO 0·0002 DYNES/CM.²
FREQUENCY IN C.P.S.

Fig. 5.
Narrow band analysis of noise spectrum (50-60,000 c.p.s.) from Ghost Lancastrian in flight. Altitude 5,000 ft. I.A.S. 190 m.p.h.

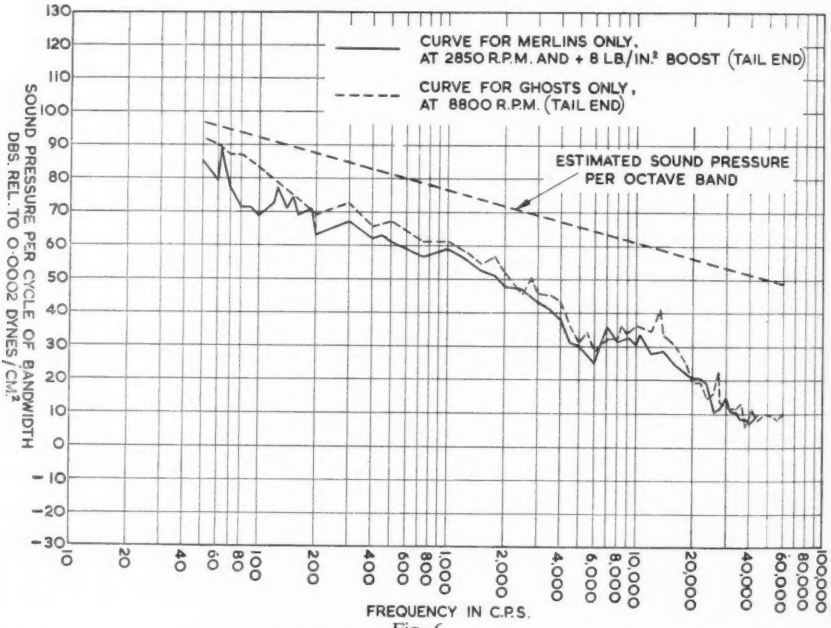
CURVE FOR MERLINS ONLY, AT 2850 R.P.M. AND + 8 LB./IN.² BOOST (TAIL END)
CURVE FOR GHOSTS ONLY, AT 8800 R.P.M. (TAIL END)
ESTIMATED SOUND PRESSURE PER OCTAVE BAND
SOUND PRESSURE PER CYCLE OF BANDWIDTH DBS. REL. TO 0·0002 DYNES/CM.²
FREQUENCY IN C.P.S.

Fig. 6.
Narrow band analysis of noise spectrum (50-60,000 c.p.s.) from Ghost Lancastrian in flight. Altitude 5,000 ft. I.A.S. 190 m.p.h.

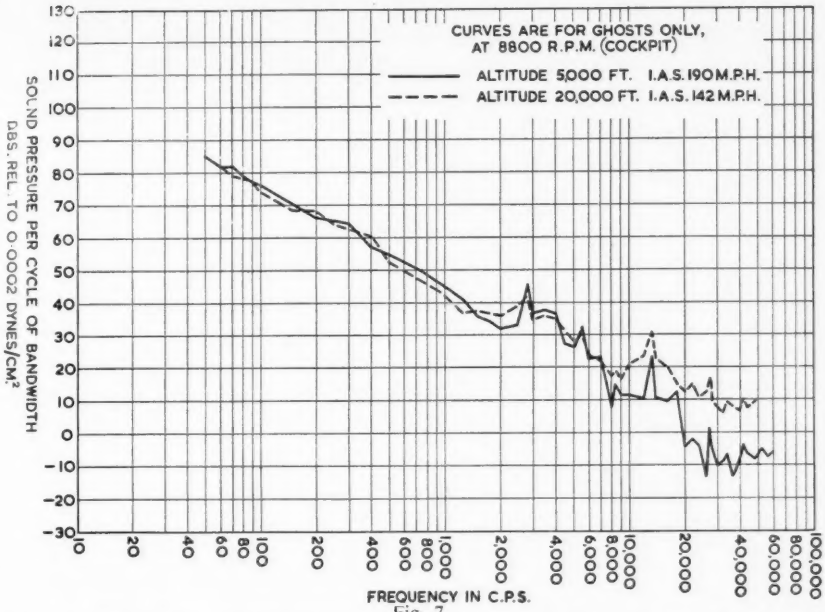
CURVES ARE FOR GHOSTS ONLY,
AT 8800 R.P.M. (COCKPIT)
ALTITUDE 5,000 FT. I.A.S. 190 M.P.H.
ALTITUDE 20,000 FT. I.A.S. 142 M.P.H.
SOUND PRESSURE PER CYCLE OF BANDWIDTH
DBS. REL. TO 0·0002 DYNES/CM²
FREQUENCY IN C.P.S.

Fig. 7.
Narrow band analysis of noise spectrum (50-60,000 c.p.s.) from Ghost Lancastrian in flight. Altitudes 5,000 ft. and 20,000 ft.

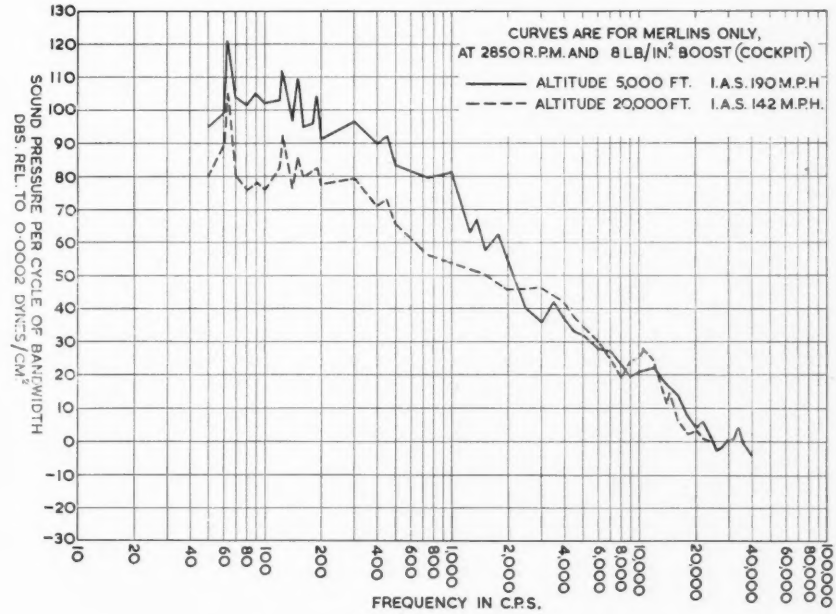
CURVES ARE FOR MERLINS ONLY,
AT 2850 R.P.M. AND 8 LB/IN² BOOST (COCKPIT)
ALTITUDE 5,000 FT. I.A.S. 190 M.P.H
ALTITUDE 20,000 FT. I.A.S. 142 M.P.H.
SOUND PRESSURE PER CYCLE OF BANDWIDTH
DBS. REL. TO 0·0002 DYNES/CM²
FREQUENCY IN C.P.S.

Fig. 8.
Narrow band analysis of noise spectrum (50-60,000 c.p.s.) from Ghost Lancastrian in flight. Altitudes 5,000 ft. and 20,000 ft.

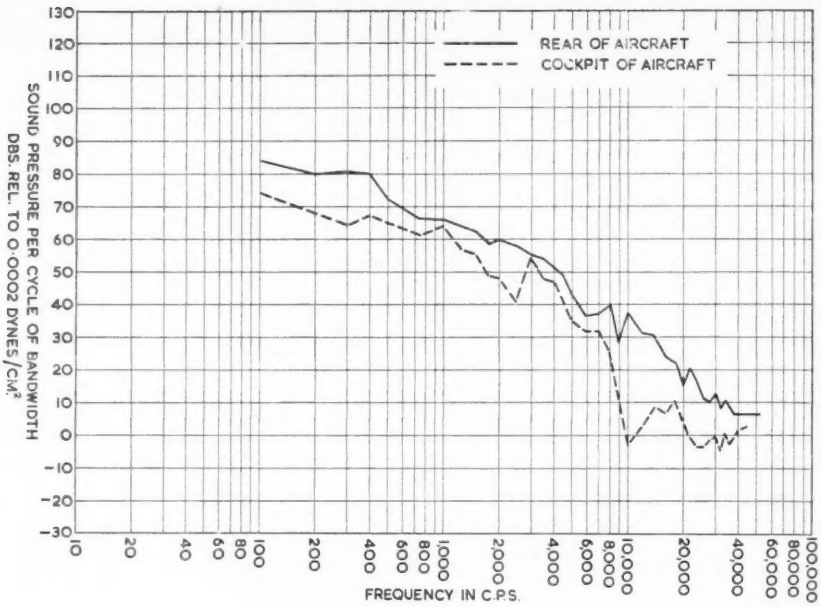


Fig. 9.
Narrow band analysis of noise spectrum (100-60,000 c.p.s.) from Ghost Lancastrian in flight. Glide from 15,000 ft. to 3,000 ft.

other using the high frequency instrument. Then the Merlin engines were stopped, their propellers were feathered and the Ghost engines were accelerated. The two Ghost engines were capable of flying the aircraft at a speed greater than 190 m.p.h., but the aircraft was flown at 190 m.p.h., using the Ghost engines only. The noise was again analysed, using the same procedure as before. In order to complete the series of experiments, the aircraft was next flown at 190 m.p.h., using the four engines but climbing steadily at a suitable angle of elevation to keep the air speed constant.

Because of insufficient time to take a complete set of measurements at 20,000 feet, only those for the pilot's cockpit were obtained; these are shown in Figs. 7 and 8.

In an endeavour to study the aerodynamic component, the aircraft was flown with all four engines developing the maximum power, at 5,000 feet, and the air speed was noted, which in this case was 305 m.p.h. The aircraft was next taken to 20,000 feet and put in a dive, with the Merlin engines shut off and their propellers "feathered" and the Ghost engines throttled back to a safe minimum speed of 3,000 r.p.m. The noise was analysed under these conditions and it was not unreasonable to assume that the major part of the total noise was due to the rush of air past the wings and the fuselage, constituting the aerodynamic component.

The location of the microphones and the analysing equipment inside the aircraft is shown in Fig. 1. The plan view of the modified Lancastrian aircraft used for these experiments is shown in Fig. 2.

## 4. EXPERIMENTAL RESULTS

Narrow band analysis curves relating frequency and sound pressure levels are given in Figs. 3, 4, 5, 6, 7, 8 and 9. Although the measurements were taken on two different types of instrument, a Constant Percentage Band-width instrument for the low frequencies, and a Constant Band-width instrument for high frequencies, the figures quoted are corrected to represent Sound Pressure for a cycle of band-width, thus giving the curves a common basis.

In aircraft noise investigations it has been customary to measure the sound pressure in bands one octave in width, plotting the observed values at the mid-band frequency.

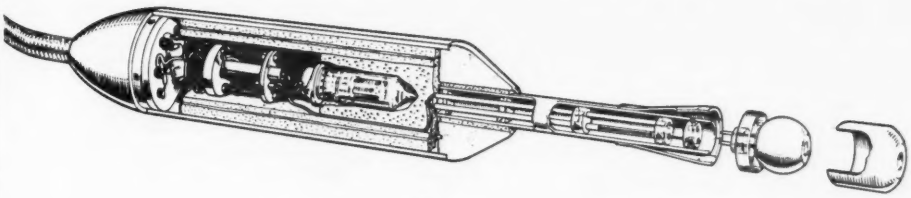

Fig. 10.
R.A.F. high frequency condenser microphone.

Although such a procedure is perhaps justified in view of the logarithmic response of the ears to pitch and the simplification in taking readings which results from the averaging out of random variations, it suffers from the disadvantage of tending to mask the existence of predominant sound components which may not be harmonically related and closely spaced in frequency. In this instance, where such conditions may be expected (*see* Section 2 (*a*)) the "finer" type of analysis is considered to be preferable.

If the results were to be compared directly with others measured on such an octave basis, a fairly tedious calculation would have to be made. The net effect, however, would be to increase the pressure values and to reduce the average slope of the curves towards the high frequency end of the spectrum by three decibels an octave. This is illustrated by the chain dotted line shown in Fig. 6.

Figure 3 shows the relation between the sound pressure levels in the pilot's cabin and in the tail for two Merlin engines running at their maximum speeds, with the two Ghost engines throttled back. Fig. 4 depicts similar comparative curves for two Ghost engines, with the Merlin engines stopped and the propellers feathered. The flight conditions were the same as in Fig. 3. In Fig. 5 the noise spectra from both types of engine are compared under the same conditions of air speed and altitude, the location of the microphone being in the pilot's cabin. Similar comparison is shown in Fig. 6 with the microphone in the tail of the aircraft. Analysis curves at these two altitudes inside

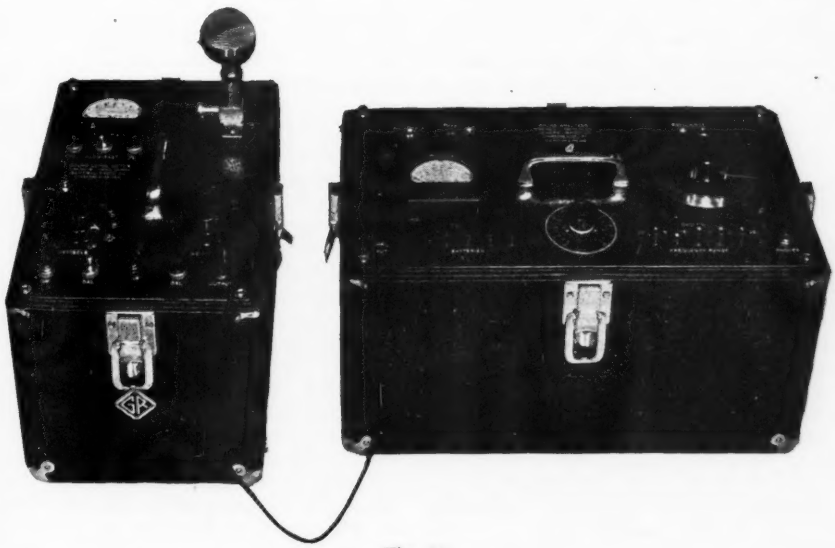

Fig. 11.
General Radio low frequency noise analysing apparatus. Frequency level 25 c.p.s. to 7,500 c.p.s.

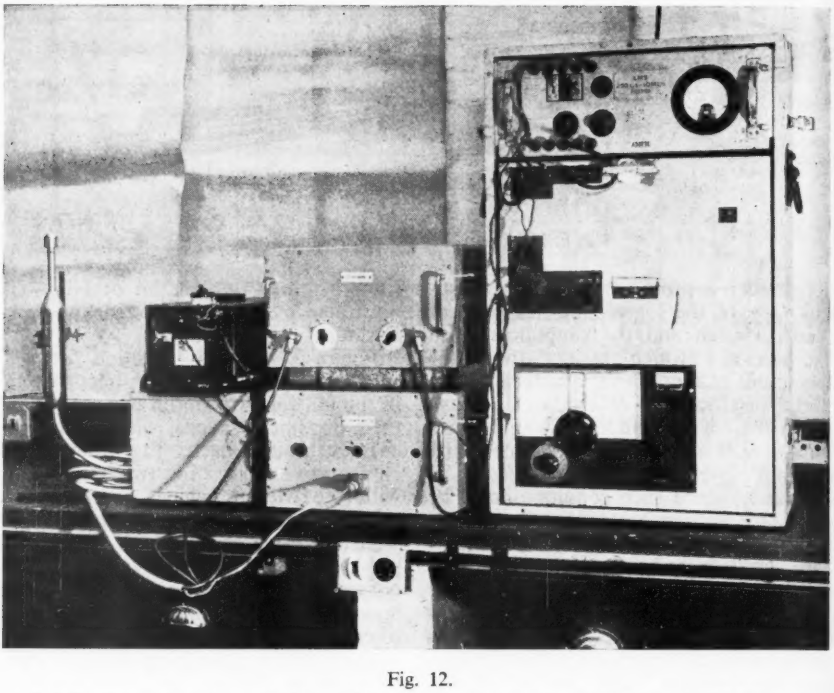

Fig. 12.
R.A.F. ultra-sonic noise analysing equipment. Frequency range 7,000 c.p.s. to 60,000 c.p.s.

the pilot's cabin for the Ghost engines are given in Fig. 7, the common basis of comparison being the same engine speed. Similar data are presented for two Merlin engines at 5,000 feet and at 20,000 feet in Fig. 8. Fig. 9 shows the noise spectrum of the aerodynamic component under conditions of dive at an air speed of 305 m.p.h., with the Merlin engines stopped and the propellers feathered and the Ghost engines throttled back to 3,000 r.p.m.

It will appear from the study of the curves in Figs. 7 and 8 that, as expected, the sound pressure levels are greater at the lower altitude because of greater density of air there, than at 20,000 feet. This relation holds true through the whole of the audio spectrum. There is a marked tendency for it to be reversed for frequencies above 20,000 c.p.s. with turbo-jet engines. Possibly, the explanation for this phenomenon is that for Merlin engines only the ultra-sonic component of the overall noise is mainly aerodynamic in origin, and therefore will decrease in sound pressure level in a more rarefied atmosphere. With turbo-jet engines, part of the ultra-sonic component is due to the harmonics of the turbine fundamental frequency, the energy in which may increase with reduced "back pressure", and part is because of turbulence at the jet, which may also increase with altitude.

It will appear from the study of Figs. 3, 4, 5 and 6 that with piston engines, more noise is produced in the pilot's cabin than in the tail. For two turbo-jet engines, however, the reverse is the case. It is assumed that both types of engine have the same propulsive power in flight. This relationship in sound pressure levels is valid up to an upper frequency limit of 15,000 c.p.s. Above this frequency, the sound pressure levels are of the same order for both types of engine of equal propulsive power. It is also interesting to note that the sound pressure level in the ultra-sonic range (up to 60,000 c.p.s. at least) is of the same order with piston engines as with turbo-jet engines at low altitudes. From a study of Fig. 7, it will be evident that at speeds above 250 m.p.h. for this particular

aircraft, most of the noise is of aerodynamic origin. Even if the engines were run at their maximum speed and produced equal sound pressure to that of the aerodynamic component, the total noise pressure level would have gone up by another 3 decibels only.

There appears to be a slight discrepancy between the indicated r.p.m. of the engines and the location of the sound pressure level peaks in the frequency scale. The same applies to the slight displacement of the peaks of noises due to the propellers, exhausts, impellers and turbines. This discrepancy is believed to be due to small errors in the revolution counters and the calibration of the frequency scales of the measuring instruments.

## 5. OBSERVATIONS

If these results may be taken as applying generally to aircraft of this type, certain broad acoustic features may be inferred. In the first place, whereas in a piston-engined aircraft the passengers should be accommodated in the rear part of the fuselage for minimum noise, the reverse applies to the turbo-jet aircraft, where the noise increases towards the tail.

An important feature of the turbo-jet engine noted in previous experiments is that the noise appears to radiate from the jet in the shape of a° cone of revolution. If the fuselage of a multi-turbo-jet aircraft is long enough to intersect these conical fields, then the sound pressure level in the tail may be very high and will be rich in high sonic frequency components.

In general, there is little evidence, however, that the turbo-jet engine constitutes a serious source of ultra-sonic energy within the aircraft. At the higher speeds possible with jet propulsion, aerodynamic noise may become the limiting factor, rather than engine noise and this may affect the apparent relative quietness of jet-propelled aircraft at comparable speeds. In view of the broad frequency spectrum of aerodynamic noise, however, adequate silencing of the passenger compartments of civil aircraft should be possible.

## ACKNOWLEDGMENTS

The author's thanks are due to the de Havilland Aircraft and Engine Companies for their kind co-operation in making available the facilities needed for the experiments described in this paper.

He also acknowledges the permission of the Director-General of Medical Services of the Royal Air Force, Air Marshal Sir Philip C. Livingston, K.B.E., to publish this paper and wishes to express his appreciation to the Royal Air Force Consultant in Otorhinolaryngology, Air Commodore E. D. D. Dickson, C.B.E., for his help and encouragement, and to the staff of the Royal Air Force Acoustics Laboratory, for making the measurements.

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# THE ANTICLASTIC CURVATURE OF RECTANGULAR BEAMS AND PLATES

by

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## 1. STATEMENT OF THE PROBLEM

The pure bending of a rectangular beam about an axis parallel to a principal axis of its cross-section is well understood if its depth $d$ is comparable in magnitude with its breadth $b$. The usual theory, noticing the geometrical fact that at any cross-section the longitudinal strains of filaments of the beam are proportional to the distances of the filaments from some neutral axis parallel to the axis of bending, postulates that the longitudinal stresses will vary in the same way. The absence of a resultant longitudinal force means that the neutral axis passes through the centre of gravity of the cross-section, and if $e$ is the longitudinal strain at a distance $y$ from the neutral axis, $p$ is the corresponding stress, $R$ is the radius of curvature of the unstrained filaments and $E$ is Young's modulus for the material of the beam, it is found that

$$e=y/R=p/E$$

giving

$$1/R=e/y\,.$$

These strains $e$ cause strains of $-\sigma e$ at right angles to them, so that the system of strains $e$, implies a similar system of transverse strains $-\sigma e$, and these imply a curvature of the beam at right angles to the original, principal, curvature, given by

$$1/R'=\sigma e/y=\sigma/R\,.$$

This curvature, $\sigma/R$, is the transverse or "anticlastic" curvature and gives rise to the sort of distortion shown in Fig. 1. This anticlastic curvature can be shown to exist in beams for which $b$ and $d$ are comparable with each other, but if $d$ is small compared with $b$, *i.e.* if the beam becomes a flat plate, it is found experimentally that there is no appreciable distortion of the cross-section, and in such cases it is usually assumed that no anticlastic curvature takes place.

The behaviour of blades, or flat plates, is discussed by G. F. C. Searle[1]. Searle points out that a small length of longitudinal filament with a net tension $T$ and a radius of curvature $r$ about the axis of principal bending experiences a resultant force acting towards its centre of curvature. Such a length, $s$, of filament is shown in Fig. 2. The resultant force towards $O$ is $2T\sin\frac{1}{2}\theta$, or when $\theta$ is infinitesimal, $T\theta$. But $\theta=s/r$ so

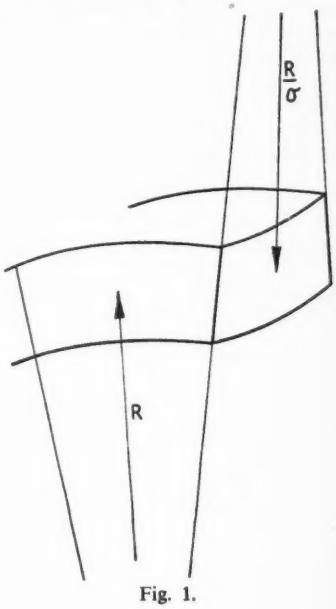


Fig. 1.

Paper received February 1947.

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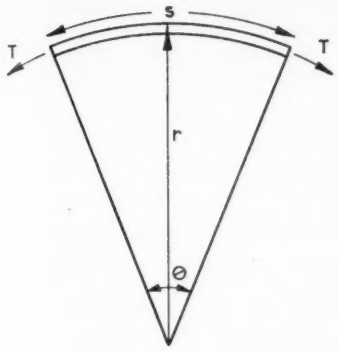


Fig. 2.

that the radial force becomes $Ts/r$ or $T/r$ per unit length of filament. Searle shows that these radial forces tend to reduce the anticlastic curvature, and estimates that it will be nearly neutralised when $b^2/(Rd)$ is greater than about six.

Case[2] investigates the question on the same lines as Searle, and also concludes that the value of $b^2/(Rd)$ decides the mode of distortion, a conclusion that is confirmed later in this paper. Both Searle and Case state that flat plates may be expected to remain substantially flat except near the edges, and Case further expects that the change from bending in which anticlastic curvature occurs to bending in which it is very nearly neutralised will appear as a definite discontinuity, rather than as a gradual change.

It is the object of this paper to determine the nature of the distortions of the cross-sections of rectangular beams of any dimensions, and to show how the transition occurs between the two types of bending.

*NOTATION*

$B, C$ defined in equations (5)
$A', B', C', D'$, constants of integration. (*See* equation (3))
$b$ = breadth of beam, *i.e.* dimension parallel to axis of bending
$d$ = depth of beam or thickness of plate
$e$ = longitudinal strain
$E$ = Young's modulus
$E' = E/(1-\sigma^2)$
$F, f$ functions defined at the end of Section (5)
$I$ = moment of inertia of undistorted cross-section of beam
$I'$ = moment of inertia of distorted cross-section of beam
$k$ = foundation modulus for beam on elastic foundation
$M$ = bending moment in beam
$p$ = longitudinal stress
$r$ = radius of curvature of any filament of beam
$R$ = radius of curvature of neutral (unstrained) filaments
$R' = R/\sigma$
$s$ = length of filament
$T$ = tension in filament
$x$ = co-ordinate measured parallel to axis of bending
$X = b/2 - x$
$y$ = co-ordinate perpendicular to $x$ – co-ordinate, in plane of typical cross-section of beam
$\alpha = \sqrt[4]{\left[\frac{3(1-\sigma^2)}{d^2 R^2}\right]}$
$\Delta$ = maximum "dip" of arc of small curvature
$\delta l$ = small element of breadth. (*See* Section 2)
$\delta x$ defined in Section 2. (*See* Fig. 3)
$\theta$ = angle subtended at axis of curvature by filament of length $s$
$\sigma$ = Poisson's ratio
$\phi = MR/EI$. (*See* Section 5)

## 2. DERIVATION OF THE FUNDAMENTAL EQUATION

Figure 3 shows the distorted cross-section of a bent beam. The neutral axis, or axis of zero longitudinal strain, has been taken as the $x$-axis. Consider the elemental strip $pqrs$, of which the sides $pq$ and $sr$ are each perpendicular to $CL$, the centre-line of the

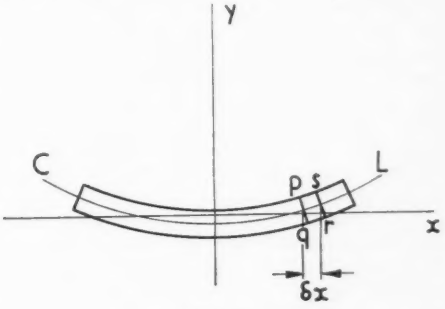


Fig. 3.

cross-section, at their points of intersection with it. As it will be shown that the slope of $CL$ is everywhere small, the distance between $pq$ and $sr$, measured along $CL$, will be called $\delta x$. Now as $\delta x$ becomes infinitesimal, $pqrs$ becomes a rectangle, so that its centre of gravity will be on $CL$.

Consider the stress system defined by the expression $p/y=E/R$.

It will be seen later that there is a second stress system to be superimposed on this, but for the moment attention will be confined to this one. The longitudinal stresses over the face of $pqrs$ are proportional to their distances from the neutral axis, and so the average stress over the element will be the stress at its centre of gravity. Thus the resultant force on $pqrs$ will be $T=(Ey/R)d\,\delta x$, where $y$ is now the distance of the centre-line from the neutral axis. $T$ will be a tension when $y$ is positive.

Thus the longitudinal strip of which $pqrs$ is a cross-section, suffers a net tension if its centre of gravity lies above the neutral axis, and a net compression if its centre of gravity lies below the neutral axis. But this strip is bent to a radius $R$, (measured to its unstrained filaments), about the axis of principal bending, and by the pressure analogy for circumferential tensions and compressions (*see* Section 1) this has the effect of a pressure of $T/R$ or $Eyd\,\delta x/R^2$ per unit length longitudinally, tending to deflect it towards the neutral axis. Thus, as Searle shows, there is a tendency for the anticlastic curvature to be neutralised.

Consider a slice of the beam whose dimension parallel to the axis of the beam is $\delta l$. This slice will be called the "transverse beam," and its dimensions are evidently length $b$, breadth $\delta l$, depth $d$. Owing to the tendency of the principal beam to bend anticlastically, this transverse beam has an "initial curvature" of $\sigma/R$, which cannot take place fully on account of the foregoing considerations, so that the curvature of the transverse beam is in general less than $\sigma/R$. This change in curvature of the transverse beam produces transverse strains which imply additional longitudinal strains in the principal beam. But no longitudinal strains can occur other than those given by $e=y/R$, so the implied additional longitudinal strains appear as changes in the longitudinal stresses. The usual theory for the transverse beam is assumed, *i.e.* that the transverse stress at any point is proportional to the distance of the point from some neutral axis, and since there can be no resultant transverse force, this neutral axis will be the horizontal centre-line of the cross-section of the transverse beam. This means that the transverse stresses due to the change in the "initial curvature" of the transverse beam add up, at any section, to a pure couple about this neutral axis. The changes in the longitudinal stresses produced by these transverse stresses are $\sigma$ times the transverse stresses producing them, so that the changes in longitudinal stresses over the face of such an element as $pqrs$ in Fig. 3, due to a change in the curvature of the transverse beam, add up to a pure couple.

In other words, the change in curvature of the transverse beam does not affect the expression for the net force on the element $pqrs$, and the effective pressure on the longitudinal strip of which the element is a cross-section, is still given by $Eyd\,\delta x/R^2$ per unit length longitudinally.

Thus the transverse beam, in effect, is subjected to a non-uniformly distributed load of $Eyd\,\delta l/R^2$ per unit length transversely, a load which is proportional to $y$, the distance of the centre-line from the $x$-axis. So the transverse beam evidently behaves as a beam on an elastic foundation.

Such beams are shown by the usual theory to have the equation

$$EI\frac{d^4y}{dx^4}+ky=0 \quad . \quad . \quad (1)$$

where $E$ and $I$ have their usual significance, and $ky$ is the load per unit length of the beam. This equation, however, depends on equating $d^2y/dx^2$ to the curvature of the beam, an approximation which demands that $(dy/dx)^2$ shall be everywhere negligible compared with unity, so that this condition must be fulfilled before the equation may be used. If anticlastic curvature took place unhindered it would be quite possible for $dy/dx$ to be large, but there is experimental evidence that the distortion of the cross-sections of all types of beams is never great, so that in practice, $dy/dx$ is always small and equation (1) may safely be used. This is confirmed later.

Therefore

$$E'I\frac{d^4y}{dx^4}+ky=0$$

where $E'=E/(1-\sigma^2)$ (by the usual theory for

beams such as the transverse beam, in which lateral contraction and extension cannot take place),

$$I=\delta l\,.\,d^3/12 \quad \text{and} \quad k=Ed\,\delta l/R^2$$

*i.e.*

$$\frac{E}{1-\sigma^2}\frac{d^3\delta l}{12}\frac{d^4y}{dx^4}+\frac{Ed\,\delta l}{R^2}y=0$$

which reduces to

$$\frac{d^4y}{dx^4}+\frac{12(1-\sigma^2)}{d^2R^2}y=0 \qquad . \quad . \quad . \quad . \quad (2)$$

This equation gives the shape of the centre-line of the distorted cross-section. Its complete solution is

$$y=\cosh \alpha x\,(A'\sin \alpha x+B'\cos \alpha x)+\sinh \alpha x\,(C'\sin \alpha x+D'\cos \alpha x)$$

where

$$4\alpha^4=\frac{12(1-\sigma^2)}{d^2R^2} \text{ or } \alpha=\sqrt[4]{\left[\frac{3(1-\sigma^2)}{d^2R^2}\right]} \qquad . \quad . \quad . \quad (3)$$

and $A'$, $B'$, $C'$, and $D'$ are constants to be determined.

Now the "natural shape" of the transverse beam is such that it has an "initial curvature" of $\sigma/R$, and this will still be true at its ends, where $x=\pm b/2$, so that

(*i*) $d^2y/dx^2=\sigma/R$ at $x=\pm b/2$.

Also, the shear in the transverse beam is proportional to $d^3y/dx^3$, and this will be zero at the ends, *i.e.*

(*ii*) $d^3y/dx^3=0$ at $x=\pm b/2$.

Finally,

(*iii*) by symmetry, $y$ is an even function of $x$.

These conditions enable $A'$ $B'$, $C'$ and $D'$ to be determined, and the equation of the centre-line is found to be

$$\frac{R\alpha^2}{\sigma}y=\frac{\sinh(\alpha b/2)\cos(\alpha b/2)-\cosh(\alpha b/2)\sin(\alpha b/2)}{\sinh \alpha b+\sin \alpha b}\cosh \alpha x\cos \alpha x+$$

$$+\frac{\sinh(\alpha b/2)\cos(\alpha b/2)+\cosh(\alpha b/2)\sin(\alpha b/2)}{\sinh \alpha b+\sin \alpha b}\sinh \alpha x\sin \alpha x\,.$$

Now $\alpha^2=\sqrt{[3(1-\sigma^2)]}/(dR)$, so that $R\alpha^2/\sigma=\sqrt{[3(1-\sigma^2)]}/(d\sigma)$, giving

$$\frac{\sqrt{[3(1-\sigma^2)]}}{d\sigma}y=\frac{\sinh(\alpha b/2)\cos(\alpha b/2)-\cosh(\alpha b/2)\sin(\alpha b/2)}{\sinh \alpha b+\sin \alpha b}\cosh \alpha x\cos \alpha x+$$

$$+\frac{\sinh(\alpha b/2)\cos(\alpha b/2)+\cosh(\alpha b/2)\sin(\alpha b/2)}{\sinh \alpha b+\sin \alpha b}\sinh \alpha x\sin \alpha x$$

$$. \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

An examination of this expression shows that if $\sigma$ is considered a constant, the relationship between $y/d$ and $x/b$ depends only on the factor $\alpha b$ and may be written

$$\left.\begin{aligned} y/d&=B\cosh \alpha b\,(x/b)\cos \alpha b\,(x/b)+C\sinh \alpha b\,(x/b)\sin \alpha b\,(x/b).\\ \text{where } B&=\frac{\sigma}{\sqrt{[3(1-\sigma^2)]}}\,\frac{\sinh(\alpha b/2)\cos(\alpha b/2)-\cosh(\alpha b/2)\sin(\alpha b/2)}{\sinh \alpha b+\sin \alpha b}\\ \text{and } C&=\frac{\sigma}{\sqrt{[3(1-\sigma^2)]}}\,\frac{\sinh(\alpha b/2)\cos(\alpha b/2)+\cosh(\alpha b/2)\sin(\alpha b/2)}{\sinh \alpha b+\sin \alpha b}\end{aligned}\right\} \quad . \quad (5)$$

These expressions were first given by Lamb[3], and have recently received experimental confirmation[4].

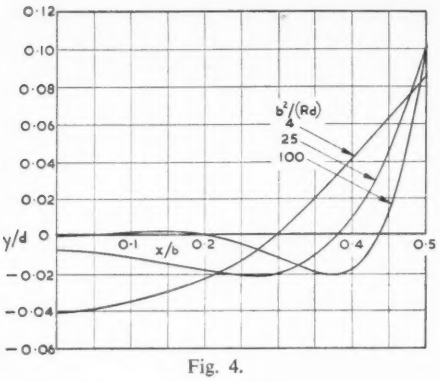


Fig. 4.

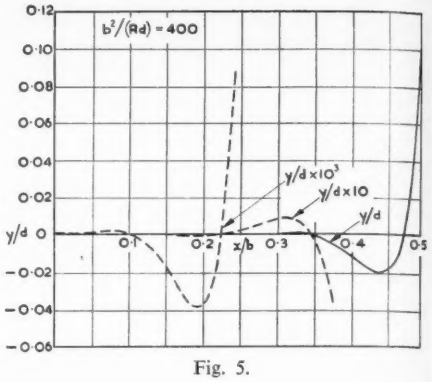


Fig. 5.

## 3. EXPRESSION OF RESULTS

It may be seen that

$$\alpha b = b\sqrt[4]{[3(1-\sigma^2)]}\,/\sqrt{(Rd)} = \sqrt[4]{[3(1-\sigma^2)]}\;b/\sqrt{(Rd)},$$

so that the relationship between $y/d$ and $x/b$ depends only on $\sigma$ and the non-dimensional factor $b^2/(Rd)$, and for a given value of $\sigma$, it is this factor which determines completely the type of distortion experienced by the cross-section. Therefore by plotting $y/d$ against $x/b$ for various values of $b^2/(Rd)$ pictures may be obtained showing the modes of distortion of the cross-sections of all types of rectangular beams for all degrees of bending. A number of such curves have been plotted in Figs. 4 and 5 for $\sigma = 1/3$. The broken lines in Fig. 5 show portions of the curve for $b^2/(Rd) = 400$ with $y/d$ magnified by 10 and 1,000 in order to show its shape more clearly.

## 4. BEAMS FOR WHICH $b^2/(Rd)$ IS VERY LARGE

From Figs. 4 and 5 it appears that if $b^2/(Rd)$ is large, the deflection of the cross-section is substantially confined to the edges of the beam, the deflections near the centre being quite small in comparison. Also, the similarity of the curves for $b^2/(Rd) = 100$ and 400 for values of $x/b$ beyond the node next nearest the edge of the beam suggests that as $b^2/(Rd)$ becomes large, the deflection near the edge of the beam may tend to some constant shape.

Now as $b^2/(Rd)$ becomes large, $\alpha b$ becomes large also, so that

(*i*) $\sinh(\alpha b/2) \simeq \cosh(\alpha b/2) \simeq \frac{1}{2}e^{\alpha b/2}$,

(*ii*) $\sinh \alpha b \simeq \frac{1}{2}e^{\alpha b}$,

(*iii*) near the edges, $\cosh \alpha x \simeq \sinh \alpha x \simeq \frac{1}{2}e^{\alpha x}$,

and (*iv*) $\sin \alpha b$ becomes negligible compared with $\sinh \alpha b$.

Using these relations we obtain from equation (4),

$$\frac{\sqrt{[3(1-\sigma^2)]}}{\sigma}\frac{y}{d} \simeq \frac{\frac{1}{2}e^{\alpha b/2}[\cos(\alpha b/2) - \sin(\alpha b/2)]\frac{1}{2}e^{\alpha x}\cos \alpha x}{\frac{1}{2}e^{\alpha b}} + \frac{\frac{1}{2}e^{\alpha b/2}[\cos(\alpha b/2) + \sin(\alpha b/2)]\frac{1}{2}e^{\alpha x}\sin \alpha x}{\frac{1}{2}e^{\alpha b}}$$

$$= \tfrac{1}{2}e^{\alpha(x-b/2)}[\cos(\alpha b/2)\cos \alpha x - \sin(\alpha b/2)\cos \alpha x + \cos(\alpha b/2)\sin \alpha x + \sin(\alpha b/2)\sin \alpha x]$$

$$= \tfrac{1}{2}e^{-\alpha(b/2-x)}[\cos \alpha(b/2-x) - \sin \alpha(b/2-x)].$$

Now let $X = b/2 - x$ (*i.e.* measure $x$ from the edge of the beam inwards, and call it $X$), then,

$$\frac{y}{d} \simeq \frac{\sigma}{2\sqrt{[3(1-\sigma^2)]}}e^{-\alpha X}[\cos \alpha X - \sin \alpha X] \quad . \quad . \quad . \quad (6)$$

where $\alpha X = \sqrt[4]{[3(1-\sigma^2)]}\,X/\sqrt{(Rd)} = \sqrt[4]{[3(1-\sigma^2)]}\,[b/\sqrt{(Rd)}]\,X/b$.

Therefore if $y/d$ is plotted against $\alpha X$, or preferably against $[b/\sqrt{(Rd)}]\,X/b$, the curve gives the shape of the edges of any bent beam for which $b^2/(Rd)$ is large (say greater than about 100). This has been done in Fig. 6.

From this it will be seen that as $b^2/(Rd)$ increases for a beam, or a set of beams, the maximum deflection occurs at the edges, and tends to about $0.1d$ (actually, $0.102d$ if $\sigma = 1/3$).

## 5. RELATIONSHIP BETWEEN CURVATURE AND BENDING MOMENT

The orthodox theory states that when anticlastic curvature is allowed to take place

$$M = EI/R,$$

and when it is completely neutralised

$$M = (EI/R)/(1-\sigma^2)$$

but the theory gives no clue as to how this change occurs. This may now be investigated.

It has been shown earlier that the stresses contributing to the bending moment consist of (*i*) the system given by

$$p/y = E/R,$$

this being the stress system which would exist if the anticlastic curvature were allowed to take place unhindered, and (*ii*) a set of stresses superimposed on (*i*), due to the change in curvature of the transverse beam from $\sigma/R$ to something less than $\sigma/R$.

Stresses (*i*) are dealt with by the usual theory and the moment resulting from them is given by

$$M_1 = EI'/R,$$

where $I'$ is the moment of inertia of the *distorted* section about the neutral axis.

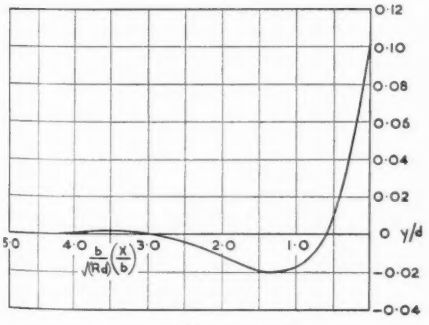


Fig. 6.

Stresses (*ii*), as shown earlier, form a system of stresses similar (but reduced in the ratio $1:\sigma$) to that arising in the transverse beam due to the change in curvature from $\sigma/R$ to something less than $\sigma/R$.

Thus the contribution per unit length transversely of this system of stresses, to the bending moment in the principal beam, will be $\sigma$ times the bending moment per unit length longitudinally in the transverse beam, which, in the usual way, will be given by

$$M' = \frac{Ed^3}{(1-\sigma^2)\,12}\,[\text{Change of } 1/R']$$

per unit length longitudinally

$$= \frac{Ed^3}{(1-\sigma^2)\,12}\left[\frac{\sigma}{R} - \frac{d^2y}{dx^2}\right],$$

or the contribution to the principal bending moment will be $\sigma M'$ per unit length transversely, giving a total contribution for the whole cross-section of

$$M_2 = \frac{\sigma\,Ed^3}{(1-\sigma^2)\,12}\int_{-b/2}^{+b/2}\left[\frac{\sigma}{R} - \frac{d^2y}{dx^2}\right]dx.$$

Thus the total bending moment in the principal beam will be given by

$$M = M_1 + M_2 = \frac{EI'}{R} + \frac{\sigma\,Ed^3}{12\,(1-\sigma^2)}\int_{-b/2}^{+b/2}\left[\frac{\sigma}{R} - \frac{d^2y}{dx^2}\right]dx$$

or if $I$ is the usual moment of inertia for the undistorted beam,

$$M = \frac{EI}{R} + \frac{Ed}{R}\int_{-b/2}^{+b/2} y^2\,dx + \frac{\sigma^2\,Ebd^3}{12\,R\,(1-\sigma^2)} - \frac{\sigma\,Ed^3}{12\,(1-\sigma^2)}\int_{-b/2}^{+b/2}\frac{d^2y}{dx^2}\,dx.$$

This can be evaluated, and expressed as

$$M = (EI/R)\,\phi$$

where $\phi$ is a function of $\alpha b$ or $b^2/(Rd)$ given by

$$\phi = \frac{1}{1-\sigma^2} + \frac{3}{2\,\alpha b}\,\mathrm{f}(\alpha b) - \frac{2\sqrt{3}\,\sigma}{\alpha b\sqrt{(1-\sigma^2)}}\,\mathrm{F}(\alpha b)$$

where

$$\mathrm{f}(\alpha b) = 2\,(B^2+C^2)\,(\sinh\alpha b + \sin\alpha b) + (B^2-C^2+2BC)\cosh\alpha b\sin\alpha b + (B^2-C^2-2BC)\sinh\alpha b\cos\alpha b + 2\,(B^2-C^2)\,\alpha b$$

and $F(\alpha b) = (B+C)\sinh(\alpha b/2)\cos(\alpha b/2) - (B-C)\cosh(\alpha b/2)\sin(\alpha b/2)$.

Again, the only variable is $\alpha b$ or $b^2/(Rd)$ (for constant $\sigma$), and in Fig. 7 is plotted percentage increase in $\phi$ against $b^2/(Rd)$ (for $\sigma = 1/3$), $\phi$ being unity when $b^2/(Rd) = 0$. It is seen that as $b^2/(Rd)$ becomes large, $\phi$ tends to a value which can be shown to be 1.125. This equals $1/(1-\sigma^2)$, which is the value given by the usual theory for beams in which the anticlastic curvature is quite neutralised.

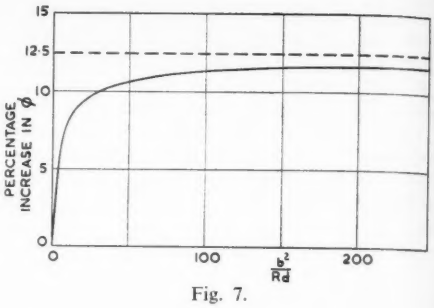

Fig. 7.

## 6. COMPARISON OF RESULTS WITH USUAL THEORY FOR $b^2/(Rd)$ SMALL

It is useful to compare the results obtained with those given by the usual theory for small values of $b^2/(Rd)$. This is of interest because the usual theory is the basis of a standard method of determining Poisson's ratio, and the beams used have a very small value of $b^2/(Rd)$.

The deflection of the beam at its edges is taken as the criterion, and the results obtained by the present theory are compared with those obtained by assuming that anticlastic curvature takes place unhindered.

*(i) Author's Theory*

The deflection at the end of the beam is given by

$$(y/d)_{x=b/2} = B\cosh(\alpha b/2)\cos(\alpha b/2) + C\sinh(\alpha b/2)\sin(\alpha b/2)$$

which reduces to

$$(y/d)_{x=b/2} = \frac{0.102(\sinh \alpha b - \sin \alpha b)}{\sinh \alpha b + \sin \alpha b}$$

(for $\sigma = 1/3$).

*(ii) Usual Theory*

Anticlastic curvature takes place so that the curvature of the transverse beam is everywhere $\sigma/R$. If $\Delta$ is the maximum "dip" as shown in Fig. 8,

$$(b/2)^2 \simeq \Delta 2R/\sigma.$$

Thus, $\Delta = (\sigma/8)(b^2/R)$.

Now the origin lies on the neutral axis, at the centre of gravity of the distorted section, and this, for an arc of small angle, is at a distance $\Delta/3$ from the lowest point. So the maximum deflection at the ends of the transverse beam is $2\Delta/3 = (2/3)\sigma b^2/(8R)$.

Therefore

$$\left(\frac{y}{d}\right)_{x=b/2} = \frac{2}{3}\frac{\sigma}{8}\frac{b^2}{Rd} = \frac{1}{36}\frac{b^2}{Rd} \text{ (if } \sigma = 1/3).$$

$(y/d)_{x=b/2}$ is now tabulated against $b^2/(Rd)$ for the two theories as follows:—

| $b^2/(Rd)$ | $\left(\frac{y}{d}\right)_{x=b/2}$ *Author's theory* | $\left(\frac{y}{d}\right)_{x=b/2}$ *Usual theory* |
|---|---|---|
| 0.25 | 0.00693 | 0.00694 |
| 1 | 0.0272 | 0.0278 |
| 4 | 0.0857 | 0.111 |
| 16 | 0.104 | 0.444 |
| 25 | 0.102 | 0.694 |

It is seen that agreement is very close for $b^2/(Rd)$ less than about one, but beyond this, the value given by the usual theory becomes considerably larger.

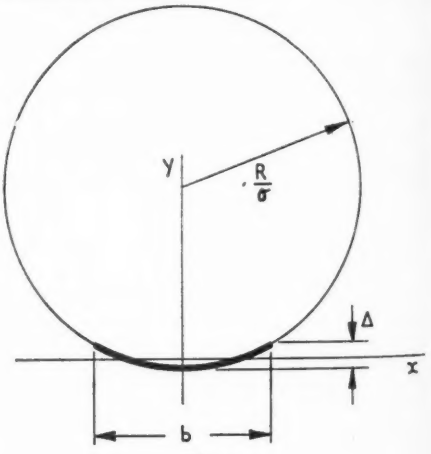

Fig. 8.

## 7. CONCLUSIONS

It is seen from the graphs and Table that

(*i*) the present theory agrees closely with the orthodox theory for small values of $b^2/(Rd)$ (say $b^2/(Rd)$ less than about one), *i.e.* for beams in which either $d$ is not small compared with $b$, or $R$ is very large,

(*ii*) for large values of $b^2/(Rd)$ the distorted cross-section changes its shape considerably, becoming undulating, the undulations decreasing in size towards the centre of the beam.

(*iii*) as $b^2/(Rd)$ becomes very large (say $b^2/(Rd)$ greater than about 100), the beam is substantially flat except near the edges where the maximum deflections tend to the value $0.102d$.

## 8. ASSUMPTIONS

It is assumed that:—

(*i*) the material has the usual characteristics as to elasticity, homogeneity, and so forth.

(*ii*) the effect of shear in the transverse beam is negligible.

(*iii*) $dy/dx$ remains small compared with unity, otherwise the equation

$$EI\,(d^4y/dx^4)+ky=0$$

is not valid, *see* Section 2, equation (1).

It is worth investigating (*iii*). Considering a beam of given dimensions and varying its radius of principal curvature, its value of $b^2/(Rd)$ will change, and its modes of distortion will be those shown in Figs. 4, 5 and 6, for the various values of $b^2/(Rd)$ and the corresponding values of $R$. The greatest slope occurs at the edges of the beam, and increases as $b^2/(Rd)$ increases. Hence the greatest slope of the centre-line occurs where $b^2/(Rd)$ is as large as possible, or $R$ is as small as possible.

Consider a beam or plate made of duralumin, for which $E$ is, say, $10^7$ lb./in.$^2$ and the elastic limit occurs at 30,000 lb./in.$^2$ From the formula $p/y=E/R$, if such a beam is bent to a radius of less than $167d$ the elastic limit is exceeded, so that this value of $R$ is assumed to be the smallest possible. For steel, this figure is about twice as great.

We have

$$y/d=B\cosh \alpha x\cos \alpha x+C\sinh \alpha x\sin \alpha x,$$

giving, when $x=b/2$, $dy/dx=\alpha d\times \mathrm{F}\,(\alpha b)$

where $\mathrm{F}\,(\alpha b)$ is given in Section 5.

Now if $R=167d$, this can be expressed,

$$\frac{dy}{dx}=\frac{\sqrt{(Rd)}}{b\sqrt{(167)}}\,\alpha b\,\mathrm{F}\,(\alpha b)\simeq\frac{\sqrt{(Rd)}}{b}\,\frac{\alpha b}{13}\,\mathrm{F}\,(\alpha b),$$

which depends only on $\alpha b$, *i.e.* on $b^2/(Rd)$. Thus $dy/dx$ for these conditions, (*i.e.* $x=b/2$ and $R=167d$), can be plotted against $b^2/(Rd)$, and if this is done, it is found that $dy/dx$ has a maximum value of about 0.022 and tends to about 0.020 as $b^2/(Rd)$ becomes very large.

Now the approximation

$$EI\,(d^4y/dx^4)+ky=0$$

depends on neglecting a term in $(dy/dx)^2$, as being small compared with unity, so that in using this expression something of the order of $(0.02)^2$, *i.e.* about 4 in 10,000, is being neglected.

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# REVIEWS

INTRODUCTION TO THE TRANSFER OF HEAT AND MASS. E. R. G. Eckert. McGraw-Hill. New York and London. 1950. 284 pp. 143 Figures. Appendix. Index. 34s. net.

This book is a revised version of an earlier German text which apparently was not published, possibly because of printing difficulties in Germany. It is designed to give an understanding of the basic physical processes of heat and mass transfer and is a valuable addition to the literature of the subject. The author is a German scientist who moved to the United States after the end of the 1939-45 War. He has worked on heat transfer for many years and has made a number of original contributions in this field. His method of approach in this book is to stress the fundamental aspects of the subject, avoiding complex mathematics on the one hand and empirical formula of undefined validity on the other.

The theories of conduction and radiation of heat are simple in principle and are presented in a straightforward manner. The main interest lies in the treatment of the convection of heat where an understanding of the fluid flow is a necessary preliminary to the understanding of heat transfer: the author deals very well with this theme. Short sections on the condensation of water vapour and on boiling liquids are included; the latter problem is still not properly understood in spite of its great industrial importance.

The section on mass transfer is welcome as it provides for the first time in book form a satisfactory treatment of the diffusion of matter from a solid or liquid under the action of an air stream. This is closely similar to heat transfer and the analysis brings out the analogy. The well-known analogy between heat transfer and skin friction is less intimate than the analogy between heat transfer and diffusion, but both are useful in aerodynamics; for example, the two analogies together provide the basis of the method of detection of the transition from laminar to turbulent flow in the boundary layer devised by Gray at the Royal Aircraft Establishment and now widely used.—H.B.S.

INTERPLANETARY FLIGHT—AN INTRODUCTION TO ASTRONAUTICS. Arthur C. Clarke, B.Sc. Temple Press. 1950. 164 pp. Photographs. Diagrams. Bibliography. Index. 8s. 6d. net.

This excellent little book is the first in what promises to be a useful series, called "Technical Trends," and appearing under the imprint of Temple Press. It is also, as far as this reviewer knows, the first book of its kind in the English language.

There have been a number of popular books on the possibilities of rocket flight beyond the atmosphere to other worlds, and a few highly technical ones, mostly written by the pioneers of the subject and now having something of the classic status enjoyed, for example, by Lanchester's works in aeronautics. There has also been at least one good volume (by Sutton) on rocket engineering, to say nothing of a mass of periodical literature. No single reference among all these, however, caters adequately for the type of reader for whom Mr. Clarke's book is obviously intended—namely, the one with some technical background but little specialised knowledge of the subject, who nevertheless wants to carry his study of it beyond the merely popular stage.

The author devotes only a brief introductory chapter to the history of his subject, and then embarks on a clear explanation of the dynamics of spaceflight and rocket propulsion. All this amounts to the application of classical celestial mechanics to the case of a "spaceship" moving along its orbital path between the planets. Later chapters cover the ideas which have so far been advanced on the form which spaceships and space stations may eventually take, the possibility that nuclear energy may be used in future rocket-type engines, and various subsidiary problems.

These latter are stated to be less fundamental than the one of propulsion, but are nevertheless admitted to be important. They include navigation, radio communication, and the degree of danger to be expected from meteors and cosmic rays. A final chapter makes an eloquent plea for the value of the achievement of interplanetary flight, in terms of both practical benefits which may ensue, and also the effects on the whole of human philosophy.

The book is well written and would be read with interest and enjoyment by any layman; most of the mathematics is relegated to an appendix, where the technical conceptions of each chapter are outlined in somewhat greater detail. However, the particular appeal will be to the technical man who feels he would like to know something of the scientific basis of the claims, so often made now, for the feasibility of spaceflight. He may pick the book up with raised eyebrows and a sceptical smile, but should put it down with a more thoughtful expression; the author does not fail to draw the obvious parallel between astronautics and the past development of aeronautics.—A.V.C.

JANE'S ALL THE WORLD'S AIRCRAFT, 1950-51. Edited by Leonard Bridgman. Samson Low, Marston & Co. London. 1950. £3 3s. 0d. net.

Mr. Bridgman, editor of "Jane's All the World's Aircraft," is a most modest man and a man who is a seeker after truth. It takes a really modest man to write with such truth these opening words of his Preface: "The annual appearance of 'All the World's Aircraft' is now accepted as an event of major importance in the World of Aviation."

How fortunate the publishers were to have a name like Jane for such a publication. How fortunate they have been in the editors who succeeded F. T. Jane. First that great polemical and palaestrical C. G. Grey disputing and wrestling with all for the sake of the aviation causes which he made his own, and now Leonard Bridgman who keeps so much of his light under bushels of modesty.

"A new feature of Section C is a list of first flights between 1st June 1949 and 31st May 1950," to quote again from the Preface. It contains the names of sixty-three aircraft, "the greater (*sic*) majority of them first prototypes," a most heartening summary. It is noted that over half of these are powered with gas turbine engines. Out of the sixty-three first flights listed, twenty-two come from the U.S.A. and eighteen from Great Britain. The respective populations are roughly three to one.

A most encouraging revival is Section E, the World's Airships! After all, something has to compete with the increasing number of gasbags in the world, political and otherwise, and, to quote again, "there is some lighter-than-air activity in the Soviet Union." It is ten years since Jane's mentioned airships, and it is hoped that what Jane publishes today will be considered outside the Soviet Union tomorrow. There is a future for airships. The reviewer looks forward to seeing a small ship flying in England next year before the May is out.

As last year, a special Addenda is published with this volume bringing information about British aircraft up to 15th September 1950; within one month of publication.

Another volume for your reference shelves if you wish to know your aircraft.—J.L.P.

THE PERFORMANCE OF CIVIL AIRCRAFT. F. B. Baker. Pitmans. London. 1950. 302 pp. Diagrams. Appendix. 35s. net.

This book, the author states, is mainly addressed to that portion of the general public who are interested in aircraft. If that is the case, it is doubtful whether such readers will proceed beyond the first two chapters, the first on elementary mechanics (Newton's laws of motion, dimensions, definitions of power, work, energy and so on) and the second on elementary aerodynamics. Even if the average reader were drawn from among pilots and air crew, which is much more likely, the first two chapters still seem out of place (the subject matter is covered in numerous other books) and are likely to deter the reader. This would be a pity because the following chapters contain a great deal of interesting and useful information, presented in a practical way.

The chapters on take-off, cruising and range, which form the bulk of the book, are particularly good and contain matter not presented together, or in a better way, elsewhere. Some of the other chapters contain little that is new and in fact almost half the chapter on "Economic Aspects of Operation" is composed of quotations from other authors. There are a number of worked examples and an Appendix contains a set of questions for the student on general aerodynamics and power plants, very few of which, however, can be answered by reference to the text.

The notation at the beginning of the book is a valuable factor, but unfortunately it is not complete or consistent. In fact, the whole volume shows a lack of co-ordination and consistency and the reader tends to feel that it is a collection of rather miscellaneous knowledge, rather than a logical sequence of information. For example, the possibilities of flying boats are dismissed in ten lines, while three pages, including nine diagrams, are devoted to a detailed explanation of how tanker and receiver make contact during flight-refuelling operations. Too often information is introduced quite casually as common knowledge, only to be defined and explained in great detail some pages later.

The production of the book is not first-class. There are a good many errors and inconsistencies, some in printing, some due to the author. For example, the interchange which has occurred of figs. 63 and 65, which are similar, could be very misleading.

In a volume which contains many useful charts and diagrams, some of which are obviously not original, it is surprising that there is only a negligible number of references (one, to the author's work, has the wrong date) and no acknowledgments at all.

Summarising, for an interesting and detailed account of cruising and take-off technique, this is a book worth buying, both for air crew and technician. Otherwise it is not.—E.C.P.

PLASTICITY OF CRYSTALS. E. Schmid and W. Boas. F. A. Hughes & Co. Ltd., London. 1950. 353 pp. 222 illustrations. Index. Appendix. Bibliography. 35s. net.

This is a translation of the well known "Kristall plastizität" published in 1935. Although 15 years old "Kristall plastizität" remains the standard to which metal physicists turn for information on problems concerned with the deformation of metal crystals. A classic in this field, it provides a comprehensive account of all the significant information on the subject up to 1934 and constitutes a very firm foundation for its study. The book is primarily of interest to the metal physicist and the metallurgist and has little direct appeal to the aeronautical engineer. Of the nine chapters, eight are concerned with single crystals. The ninth chapter, only, deals with polycrystalline technical materials and this in the light of the detailed behaviour of the individual crystals composing them.

The early chapters provide excellent summaries of the crystallographic fundamentals and elasticity theory necessary for the study of crystal deformation, and methods of growing single crystals and determining their orientations are described. The geometry of the processes of slip and twinning is considered in detail. The description and critical discussion of the results of experimental investigations into the behaviour of metal crystals constitutes the major chapter, about half the book, and ranges over such subjects as recrystallisation and grain growth in addition to observations on the deformation processes themselves. This is a comprehensive chapter and deals with both plastic deformation and fracture; the effects of different types of stress system, temperature and speed of deformation are included and fundamental results are well tabulated.

As is to be expected, it is in the theoretical treatment of plasticity and strength that one is most conscious of the age of the book. During recent years considerable advances based on the concept of dislocations have been made in this field; when the book was prepared the first papers by Taylor, Orowan and Polanyi, on the dislocation theory of plasticity had just appeared.

The book is closely documented throughout; there is a bibliography of 703 references classified in relation to the text. Perhaps the only criticism of the book arises in this connection. In places, conclusions, results or illustrations are quoted with insufficient explanation for the full appreciation of their significance. The subject matter is well indexed, but there is no name index, an omission partly redeemed by the arrangement of the bibliography.

The translation is excellent and the book is attractively produced. The thanks of many who do not read German with facility will go out to the publishers.—R.K.

MODERN GAS TURBINES. Arthur W. Judge. Chapman & Hall Ltd. 1950. (Second Edition). 388 pp. 255 illustrations. Appendix. Index. 32s. 0d. net.

This book has been revised by the addition of a chapter of 73 pages on "Recent Progress and Developments," and certain small corrections and improvements have been made to the original text. The Bibliography has also been extended appreciably. The new chapter deals with "various new types and installations in the fields of locomotion, aircraft, marine and stationary plant." Combustion considerations, fuels, heat exchangers, thrust augmenters and materials are some of the subjects of which new developments are discussed. The automobile gas turbine is also considered and a review is given of progress in gas turbine work at various firms.

This is a most useful addition to a much-used work.—E.C.P.

HISTORY OF UNITED STATES NAVAL AVIATION. Captain Archibald D. Turnbull, U.S.N.R., and Lieut.-Commander Clifford L. Lord, U.S.N.R. Yale University Press. 1949. Geoffrey Cumberlege. Oxford University Press. 1949. 323 pp. 16 pp. illustrations. Index. $5.00.

What makes a good book on history? Is it no more than a painstaking collection of the abstract and brief chronicles of Time—or is it, as with Macaulay and Gibbon, the spirit of the author which interprets the records? If it is the latter, then any book of joint authorship must lack in personality. This book wallows in quoted memoranda and digressions on the boring arguments pro and con whether naval aviation should be or not, although a glimmer of interest is aroused by official advices of the backwardness of the U.S. Navy as regards its aviation in 1914-18—which is not the less surprising since the first deck landing and take-off credits must go to America.

But, for the serious-minded Staff College reader this book does provide useful material at intervals, if only as a warning of what the Staff mind can get to if it is really extended. One feels that Alexander Woollcott would have commented that these authors have certainly worked their passage, even if they were sea-sick with words most of the trip. English readers will be grateful for the kind references to the R.N.A.S. on page 81, although a few hollow laughs may be heard off stage at the remark that the British Admiralty was "pushing aviation vigorously." The question is where?—B.J.H.

AIRPLANE PERFORMANCE, STABILITY AND CONTROL. Perkins and Hage. *Amendment to review published in September* 1950 JOURNAL.

In the review of this book which appeared on p. 607 of the September 1950 JOURNAL it was stated "... even such an elementary matter as reversal of aileron control due to wing twist is omitted." This does the authors an injustice, which the reviewer much regrets, for the fall-off in aileron effectiveness due to wing twist is briefly discussed on p. 358 of the book. It is true, however, that the theory of this loss of effectiveness is not given and the item "reversal of control" does not appear in the index. The reviewer would plead this in extenuation of his faults.—W.J.D.

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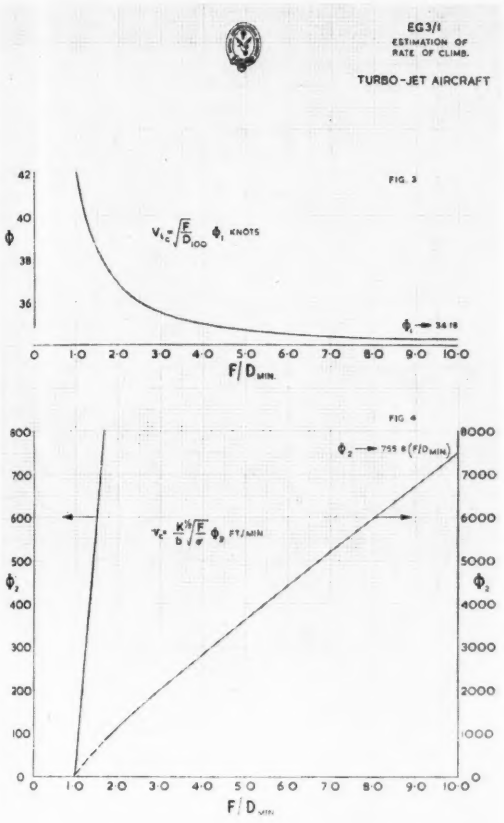
Telephone: Grosvenor 3515 (5 lines). Telegraphic Address: Didaskalos, Audley, London.

It is regretted that because of the increasing costs of production it has been found necessary to increase the price of the Journal. From January 1951 (Volume 55, Number 481) the price of a single copy will be increased to 10s. (10s. 3d. including postage), and annual subscriptions to £6 3s. 0d., including postage.




# Performance Data Sheets

## ON

## PERFORMANCE ESTIMATION

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**New Sheets are now printing and will be available shortly on Performance Estimation and on Piston Engine Performance Reduction as a Section of the Data Sheets on Performance.**

**Sheets are already available on Instrument Corrections and on Turbo-Jet and Turbo - Prop Performance Reduction.**

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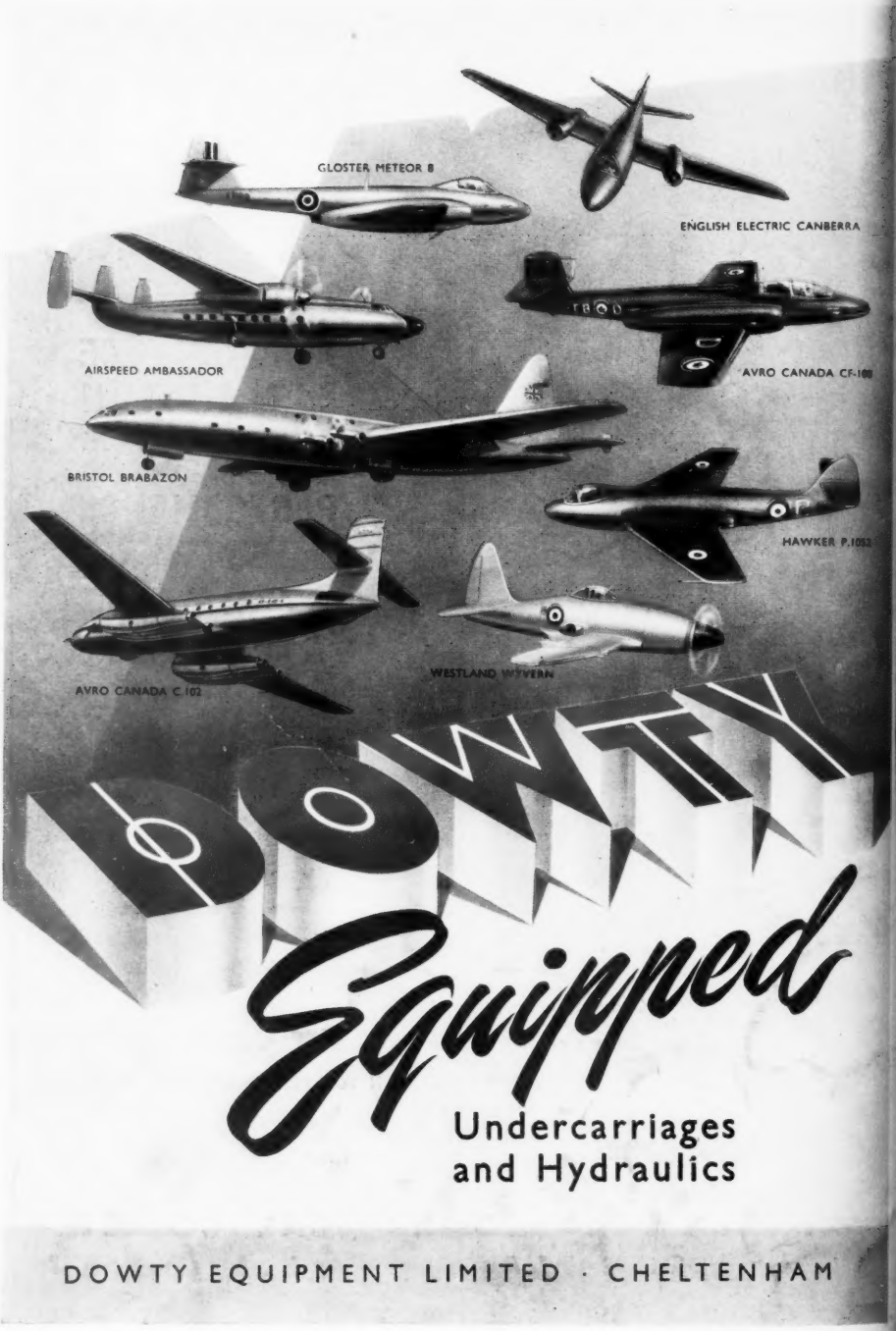


Printed by the LEWES PRESS (Wightman & Co. Ltd.), Friars Walk, Lewes, England, and Published by THE ROYAL AERONAUTICAL SOCIETY, 4 Hamilton Place, London, W.1, England.